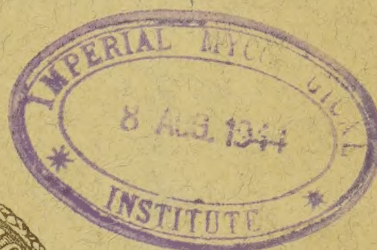
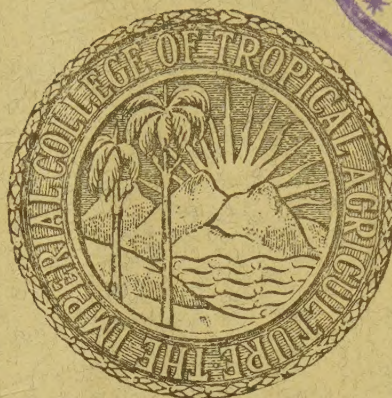


ELEVENTH REPORT ON CACAO RESEARCH 1941-43



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GOVERNMENT PRINTING OFFICE,
PORT-OF-SPAIN

1944.

CONTENTS

A.—BOTANICAL SECTION

	PAGE
THE BOTANICAL PROGRAMME, 1941-43	3
PROGRESS REPORT ON FIELD EXPERIMENTS	4
THE INCIDENCE OF CACAO BEETLE DAMAGE ON SOME I.C.S. CLONES PLANTED AT RIVER ESTATE	15
SOME OBSERVATIONS ON I.C.S. CLONAL MATERIAL AT RIVER ESTATE	17

B.—CHEMICAL AND ECOLOGICAL SECTION

THE CHEMICAL PROGRAMME, 1941-43	22
A. STUDIES IN THE PHYSIOLOGY OF <i>THEOBROMA CACAO</i> WITH SPECIAL REFERENCE TO CHERELLE WILT	
FURTHER PROGRESS REPORT	23
B. DORMANCY OF CACAO BUDS:	
(I) A CONSIDERATION OF THE FACTORS CONCERNED IN THE BREAKING OF THE REST PERIOD	28
(II) CARBOHYDRATE CHANGES DURING THE DEVELOPMENT OF A FLUSH	33
(III) THE RELATIONSHIP BETWEEN BUD-BURSTING AND GROWTH OF THE WHOLE TREE	37

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ELEVENTH REPORT ON CACAO RESEARCH, 1941-43

A. BOTANICAL SECTION

THE BOTANICAL PROGRAMME, 1941-43

By E. E. CHEESMAN

THE work of the Botanical Section in the period under review was mainly concerned with the field experiments. Good maintenance of the area planted up to 1941 (a little more than 12 acres at River Estate) was hampered by an acute shortage of labour, and has been achieved only at the expense of extension. No new plantings were made in either 1942 or 1943, or are contemplated for 1944. Present facilities are just sufficient to keep up the seven experiments numbered CRB. 1 to CRB. 7 and to make the necessary observations on them, and they merit full attention because they are now giving useful and interesting results.

Yield records are being kept from the time when the trees attain three years of age, and thus have now been taken on CRB. 1 for three years, on CRB. 2 for two years, and on CRB. 3 for one year. With CRB. 4 being recorded in the current crop year, there are at the time of writing 2,304 trees to be harvested and recorded individually every month.

The results for the crop years 1940-1941 and 1941-1942 were somewhat disappointing, for reasons clearly connected with the weather. The dry seasons of 1941 and 1942 were both severe, that of 1942 being the worse. These seasons caught the oldest trees at the critical age, when they were above the ground-shade whilst the permanent shade had not yet developed adequate protection for them. Consequently, yields were below expectation; but the trees suffered little permanent damage, and with a more favourable season in 1942-43 they put up a performance which is highly encouraging.

To summarize the figures given in more detail in the body of the Report: the five-year trees of CRB. 1 yielded at a rate of 282 lb. dry cacao per acre; the four-year trees of CRB. 2 gave 367 lb. per acre; and the three-year trees of CRB. 3 gave 231 lb. per acre. As in each set there are some clones of very poor performance, these overall figures do not reveal the merits of the better clones. In CRB. 1, the best three clones averaged 511 lb. per acre; in CRB. 2, the best five clones averaged 430 lb. per acre; and in CRB. 3 the best four clones averaged 284 lb.

As I.C.S. 1 occurs in every set, the three experiments comprise 16 clones, and 10 of them have given good yields, whilst 6 are still poor. In general, this broad result is much what was to be expected in the field testing of selections, and

the proportion of clones failing on the test is not unduly high. The standard clone I.C.S. 1 happens to have been the best performer in all three sets, and gave 354 lb. per acre on the three-year-old, 591 lb. on the four-year-old, and 651 lb. on the five-year-old trees. These yields were obtained in spite of heavy infestation of Witches' Broom disease all over the estate, and on a field which when in seedling cacao 40 years old was giving an average of 561 lb. per acre.

So far as Witches' Broom disease is concerned, it is important to note that this young clonal material has hitherto avoided serious pod infection by setting and maturing its main crop during the dry season. Thus the loss from this cause for the whole crop year was only 14 per cent. in CRB. 1 and lower in the other experiments. But in February more than 60 per cent. of the few pods reaped were diseased, and the low final figure was due to the fact that about two-thirds of the season's crop was reaped in July with infection almost nil. Therefore, if the trees as they age change their habits and bear their main crop in November-March like old seedling cacao, their losses from Witches' Broom are likely to be much more serious. Meanwhile, their partial avoidance of the disease is fortunate, as allowing a fair assessment of their potential yielding power in the absence of disease.

Our intention was to publish and discuss the figures for 1940-41 and 1941-42, and the results were analysed and written up for that purpose; but the publication of this Report was delayed so long by factors outside our control that the 1942-43 results became available before the earlier ones had been set up in type. It then became clear that in the light of the later figures the earlier ones had very little value, and that the best and most economical course was to delay the Report a little longer and rewrite it.

Acknowledgment is due to the officers whose work, but for this change of plan, would have appeared under their own names. The yields in 1940-41 were recorded and analysed by Mr. R. K. McKee, who also recorded the results up to the end of the crop year 1941-42, when he resigned in order to join H. M. Forces. Mr. H. Doggett had charge of the experiments in the crop year 1942-43, recorded the yields, and analysed some of Mr. McKee's records as well as his own before leaving on transfer to another Colony. Analyses were completed by Mr. W. H. C. Knowles.

Mr. G. E. L. Spencer of the Botanical Department of the College rendered his usual valuable co-operation in the field work up to July, 1942. He was then away for more than a year, adding to his knowledge of cacao in Mexico and Central America, and on his return took charge of the experiments for the current year.

This summary must mention that quite as interesting at this stage as the actual yields are some of the ancillary characters, for the observation of which the plantings of clonal cacao are particularly useful. The Mycology Department of the College has used them for investigating clonal differences in susceptibility to Witches' Broom Disease and found statistically significant differences between clones, which have already been reported elsewhere.*

Mr. McKee has been able to demonstrate similar differences in susceptibility to attack by cacao beetle, which are noted in the body of this Report.

Other clonal differences in behaviour were studied by Mr. McKee in detailed observations of flushing and flowering over a period of 21 months. With respect to flushing, he finds the differences to be very slight, and although they may become more marked as the trees age, they do not at present seem to have any great importance. Differences in flower production, and in the proportion of cherelles set to flowers produced, are much greater; but so far the most striking differences in these respects are those between self-compatible and self-incompatible clones, and the results tend to confirm those of earlier observations on seedlings.

* Baker, R. E. D. and S. H. Crowdy. Notes on the susceptibility of I.C. Selections at River Estate to Witches' Broom Disease of Cacao. *Trop. Agriculture*, XIX (1942), pp. 207-9.

Baker, R. E. D. Further notes on the susceptibility of I.C. Selections at River Estate to Witches' Broom Disease of Cacao. *Trop. Agriculture*, XX (1943), pp. 156-8.

PROGRESS REPORT ON FIELD EXPERIMENTS OF THE BOTANICAL SECTION TO AUGUST, 1943

By E. E. CHEESMAN

GENERAL NOTES ON EXPERIMENTS CRB. 1 TO CRB. 6*

Weather. The monthly rainfall figures for River Estate from January 1941 to June 1943 are given (by courtesy of the Trinidad Department of Agriculture) in Table I. They show by

Table I

RAINFALL AT RIVER ESTATE, 1941-43

	Average 1921-1940	1941	1942	1943
January ...	3.44	1.30	0.89	7.74
February ...	1.70	0.56	0.67	3.69
March ...	2.09	1.48	Nil	2.60
April ...	2.10	0.46	4.08	2.14
May ...	3.56	3.07	8.02	6.52
June ...	6.81	5.58	5.20	4.00
July ...	9.12	8.82	13.91	13.33
August ...	10.04	10.14	13.63	18.29
September	8.47	13.14	11.40	5.19
October ...	7.01	6.65	11.12	2.99
November	7.82	5.77	7.27	5.70
December...	6.86	5.64	10.26	4.66
Annual ...	69.02	62.61	86.45	76.85

comparison with the averages for the preceding twenty years that the dry seasons were severe in both 1941 and 1942, but that the early months of 1943 were moister than usual. The monthly figures alone do not bring out the full significance of the differences between the seasons, which are perhaps better indicated by the number of rainless days in the first four months of the year. The number of rainless days among the 120 days of January 1st to April 30th was 95 in 1941, 105 in 1942, and 71 in 1943. The severity of the 1942 dry season is further shown by the fact that in that year there were 55 consecutive rainless days from 18th February to 13th April. Rainless spells at this time of the year are associated with bright sun and enough breeze to have a strong drying effect on plants and soil alike, and this drying effect is probably more serious than the actual lack of precipitation itself. Thus the effect of rainfall distribution on the young cacao is often more marked to officers making weekly observations in the field than would be expected from mere inspection of rainfall figures.

The seasonal effects naturally differed somewhat on the different plantings according to their age.

Agricultural Treatment. The treatment of the experiments has been hampered throughout the period under review by shortage of labour, and

*For particulars about the numbering of these experiments, their objects, composition and establishment, reference should be made to the Tenth Annual Report on Cacao Research (1940) pp. 3-11.

has inevitably fallen below the standard which we set ourselves in normal times, but all essential operations have been carried out. These include weeding, removal of sucker growth, witches brooms and cacao beetle larvae, necessary replacements of damaged trees, and adjustment of shade so far as it can be controlled through the bananas which still remain in the field.

A major problem throughout the field has been caused by irregular growth of the young immortelles put in for permanent shade. As stated in the general notes on these experiments in the Tenth Report, "*Anauca*" immortelles (*Erythrina Poeppigiana* (Walp.) O. F. Cook) were planted with the cacao at 24 × 24 feet, to be reduced later to 48 × 48 feet leaving a permanent shade tree at each corner of each 16-tree plot. It was hoped that the *Erythrina* would provide a fair canopy by the time that the bananas, planted at 12 × 12 feet for temporary shade, had to be removed; but the expectation was not realized. Therefore up to the end of 1943 it was necessary to leave some banana stools even in CRB. 1, to provide shade in the more open places during the dry season. Old bananas, however, are very liable to fall and damage the cacao, and the procedure has therefore been to cut back the bananas towards the end of each dry season, but to allow suckers to grow up again to provide shade in the next dry spell.

In any young cacao planting in which permanent shade is included, there is inevitably a rather critical period about the third, fourth and fifth years. At this time the temporary ground shade ceases to be effective and the permanent shade has not yet begun to function efficiently. We

have had nearly half the field in this condition throughout the period under review, but the oldest plantings are now closing in satisfactorily and in the near future it will be necessary to begin thinning the immortelles to their final stand.

Experiment CRB. 1 (1941-43)

Treatment. The cacao was given its first general pruning in February 1942. Previously, trimming had been restricted to removal of dead wood and sucker growth, but on this occasion more attention was paid to shaping the young trees, particularly by the removal of very low branches and the shortening of whippy ones. Subsequently, opportunity has been taken during the regular removal of vegetative Witches' Brooms to keep the trees in good shape, for which as a rule only a very light pruning is necessary. The object is to keep the canopy as low as possible, making just enough clearance above the ground to facilitate access to the trunks.

A basket of pen manure and 1 lb. sulphate of potash were supplied to each tree in January 1941, and 1 lb. sulphate of potash again in March 1942. No manures were applied in 1943.

Composition. The composition of the planting with respect to age groups is shown in Table II. With the exception of I.C.S. 5, there has been a practically complete stand of trees since 1939. Only some 10 per cent. were less than 5 years old in 1943 and the number less than 4 years old was negligible. Of the 576 trees in the experiment, 492 (85 per cent.) were "originals", and the necessary supplies of 1939 were fairly evenly distributed among the clones.

Table II
COMPOSITION OF CRB. 1 IN CROP YEAR 1942-43

Clone	Type	Trees planted in 1937 or 1938	Supplies of 1939	Supplies of 1940	Missing
1	Buds	41	7	—	—
	Cuttings	43	5	—	—
3	Buds	43	4	1	—
	Cuttings	47	1	—	—
4	Buds	41	5	2	—
	Cuttings	44	4	—	—
5	Buds	36	4	1	7
	Cuttings	29	5	—	14
6	Buds	42	4	—	2
	Cuttings	44	4	—	—
8	Buds	37	11	—	—
	Cuttings	45	3	—	—

Heterogeneity in age is not likely, therefore, to have affected seriously the comparison of clonal performance. Nevertheless there is an undesirable degree of heterogeneity, almost inevitable in young cacao. Presumably the effect on tree to tree variance in yield is now at a maximum and will tend to disappear in time. In other words, when the oldest trees in the field are, say, twelve years old, there will be very few younger than ten years, and a mixture of ten, eleven and twelve-year trees may be expected to be much more even in performance than a mixture of three, four and five-year trees, because it is in the early years that yield rises most steeply with age.

Yields. The first recorded picking was in May, 1941 and as far as possible harvesting was done monthly thereafter. The "crop year" is supposed to run from 1st August to 31st July, but in both 1941 and 1943 there were enough pods left on the trees in August to warrant extending the period by one month, whilst in 1942 there was virtually no crop at all after July to the end of the calendar year. For these three years therefore, it has been more convenient and also more accurate to take the crop year as from 1st September to 31st August. Yields for 1942-43, grouped by sub-plots, are given in Table III, and yields for the whole period are given in less detail in Table IV. Pod value (number of pods to make 1 lb. dry cacao) have been calculated on the assumption that 1 kilogram of wet cacao gives 0.88 lb. (400 g.m.) dry cacao.

The pod values are of interest as a reflection of the conditions under which the crops matured. In 1940-41 with a moderately severe dry season during their development, the pods were roughly three-quarters of the size to be expected from the pod values of the parent trees. In 1941-42, with a very severe season, they were still smaller,

and in some cases less than half their expected size; at the same time even the total yield of some clones fell, in spite of the trees being a year older. In 1942-43 the pod values have approached the parental levels, and the average is above the selection standard of 7.5 pods to 1 lb.

Clonal differences are further discussed below but it is obvious from Table IV that this experiment contains (on their present showing) three good clones and three poor ones. The poor ones lower the average yield per picket for the whole planting to 0.93 lb. dry cacao, equivalent to 282 lb. per acre, which would not be bad for five-year-old seedling cacao, but is disappointing for selected material. But I.C.S. 1, 6 and 8 together (288 trees, covering in the aggregate nearly an acre) average 1.70 lb. per picket, or 511 lb. per acre, whilst I.C.S. 1 by itself gives 2.17 lb. per picket or 651 lb. per acre.

Analysis. The statistical analysis of the 1942-43 figures (carried out by W. H. C. Knowles) shows significant differences between blocks, clones, and propagation treatments.

The order of the blocks is 1, 6, 2, 3, 5, 4, with the group 1, 6, 2, 3 significantly better than the group 5, 4. The block order, with one important exception, has been fairly consistent over the three years. Omitting Block 6, the order of the remaining five blocks was:

1940-41 1, 3, 2, 4, 5.
1941-42 1, 3, 2, 4, 5.
1942-43 1, 2, 3, 5, 4.

This suggests that there is a fertility gradient from the north-west corner of the field (Block 1) running south-easterly, and that assumption is supported by the yields of Blocks 2 and 3 in CRB. 2, which lie adjacent to Blocks 5 and 4 respectively of CRB. 1. Block 6 both in 1940-41 and in 1942-43 came just above Block 2, a performance perfectly consistent with its position in the field on the same assumption; but in

Table IV

YIELDS AND POD VALUES IN CRB. 1, 1940-43

Crop Year		ICS 1	ICS 3	ICS 4	ICS 5	ICS 6	ICS 8	Total
1940-41	Healthy pods ...	280	66	223	55	224	369	1217
	Kilos wet cacao ...	31.597	7.660	21.459	6.827	30.583	41.588	139.714
	Pod value ...	10.0	9.8	11.8	9.1	7.3	10.1	9.9
1941-42	Healthy pods ...	511	57	226	29	223	564	1610
	Kilos wet cacao ...	53.244	5.208	19.445	3.738	32.909	61.340	175.884
	Pod value ...	10.9	12.4	13.2	8.8	7.7	10.4	10.4
1942-43	Healthy pods ...	1575	94	185	73	871	985	3783
	Kilos wet cacao ...	232.469	12.983	27.154	12.272	169.204	156.102	610.184
	Pod value ...	7.7	8.2	7.7	5.9	5.8	7.2	7.0
Aggregate 1940-43	Healthy pods ...	2366	217	634	157	1318	1918	6610
	Kilos wet cacao ...	317.310	25.851	68.058	22.837	232.696	259.030	925.782
Parental pod values		6.3	6.1	6.7	6.0	5.4	5.5	

1941-42 (the year of severe drought) it gave only half the yield of 1940-41 and fell between Blocks 4 and 5. There may be here an interesting reaction between soil and weather, worth further study if it occurs again when the trees are older. On the other hand the figure for 1941-42 might be accidental, and no conclusion is to be drawn from it at present.

The block differences possibly depend to some extent on differences in planting dates and may tend to even out with age. In 1940-41 the best block yielded nearly four times as much cacao as the worst; but in 1942-43 only twice as much. In the abnormal year 1941-42 the best block yielded more than eight times as much as the worst, which again suggests interactions of soil and weather possibly worth study if observed when the trees are older.

For the present it can only be said that CRB.1 is clearly not as uniform as could be desired, and much of the heterogeneity seems ascribable to the soil. Blocks 1, 4 and 5 are planted with chupon material and Blocks 2, 3 and 6 with fan material, but the difference between the two types is not statistically significant, as must be obvious from the fact that the best and the worst blocks in the set are planted with the same type of material.

The comparison of the clones, which is the main object of the experiment, has given very striking results. The order of the clones from highest yielder to lowest in 1942-43 was 1, 6, 8, 4, 3, 5 and the critical difference ($P=0.05$) 27.85 kilos. Thus I.C.S. 1 performed significantly better than all the other clones, and both I.C.S. 6 and I.C.S. 8 are very significantly better than any of the remaining three clones. There is no significant difference between I.C.S. 6 and 8, or within the group 4, 3, 5.

The outstanding fact is that the six clones fall into two very distinct groups, and this has been obvious in each of the three years, although there have been variations in order within each group. It is of some interest to notice in passing that all the clones in the "good" group showed some increase in yield, even if a small one, in the unfavourable year 1941-42, whilst all the clones in the "poor" group gave less cacao in that year than in 1940-41. Furthermore, at the end of their sixth year from planting all the good clones show a much steeper increase of yield with age than any of the poor clones.

I.C.S. 1 has shown the steepest increase, the ratio of the yields in the three years being 100 : 168 : 736. Thus though giving less than I.C.S. 8 in the first two years, it came to the top with a wide margin at 5 years old. As the standard clone against which the others are compared, I.C.S. 1 has been more planted than any of the others, and to date its behaviour everywhere is highly satisfactory from the yield point of view whilst in other characters it seems to be what a standard ought to be—neither outstandingly good nor outstandingly poor.

I.C.S. 6 appears to be a little later in developing its yielding power than either I.C.S. 1 or I.C.S. 8. The ratio of its yields in the three years

was 100 : 108 : 557, and its position third for the first two years, rising to second in 1942-43. It suffered more from the unfavourable season of 1941-42, and barely increased its yield at all in that year, but made a sufficiently good recovery to pass I.C.S. 8 in the next year. I.C.S. 6 has the largest pod of any clone in this set, and is regarded as very promising all round.

I.C.S. 8 is the earliest bearer of the three, and held first place for two years, but then fell behind, the ratio of its yields in the three years being 100 : 147 : 375. Even in the third year it held many more pods than I.C.S. 6 (1258 against 916) but lost a far higher percentage by Witches' Broom, and also has a lower pod value, so that between the two factors its yield of wet cacao was less. There are evident possibilities of further changes of order among these three clones, but they are all very satisfactory all round, up to date.

In the "poor" group there are some interesting differences in behaviour, suggesting different causes of poor performance beside intrinsically low yielding power. I.C.S. 5 in particular is outstandingly susceptible to attack by cacao beetle (*Steirastoma depressum* L.) and nearly one-quarter of the trees have been killed outright (cf. Table II) whilst many others have been badly damaged. It is not a very vigorous grower, and the survivors are still far from closing in to form a canopy, and thus the plots occupied by this clone are conspicuously open places in the field wherever they occur. Inherent weaknesses have clearly been accentuated by the drought of 1942 and by the generally unsatisfactory shade on CRB. 1, and although under the conditions of the experiment it must be ranked as a valueless clone, I.C.S. 5 on another site where establishment was easier might perform relatively well. Nevertheless there is no hint of promise in the figures as they stand. The best tree of the 96 planted has matured only 13 pods up to the end of its sixth year, and as the clone is known to be self-incompatible, its large pod would appear to be its only merit.

I.C.S. 4 is also very susceptible to beetle damage, but being a strong grower it recovers better than I.C.S. 5 and is rarely killed outright. It has had more Witches' Brooms cut out of it than any other clone in the set, and may have been checked in consequence. But in 1943 the high yielding I.C.S. 1 had nearly as many brooms removed, and actually more infected cushions, and so Witches' Broom can hardly be the chief factor operating in the low yield of I.C.S. 4. Reference to Table IV will show that this clone seems to be standing still, as at five years old it had little more cacao (and actually fewer healthy pods) than it bore at three years old. No reason can be adduced at present for its behaviour.

I.C.S. 3 is not outstandingly susceptible either to beetle or to Witches' Broom, being in the middle class in both respects. It established easily, has no missing trees, and out of crop looks as well as any of the other clones. Yet the yield remains negligible. The best that can be said

of I.C.S. 3 is that its rate of increase with age is better than that of I.C.S. 4, whilst its general vigour is much above that of I.C.S. 5. Possibly it is a genuine late bearer, which will improve as it ages; but a very great improvement will be necessary to lift it into the "good" class.

So far, the broad differences between "good" and "poor" clones are increasing markedly with age. In 1940-41, I.C.S. 1, 6 and 8 together gave 75 per cent. of the total crop; in 1941-42 they gave 84 per cent. of the total crop; and in 1942-43 their contribution reached 92 per cent. It happens in this experiment that the good clones are all self-compatible and the poor ones all self-incompatible, but compatibility in this instance appears to have very little to do with the results.

The various *propagation methods* have not yet given conclusive results, although the figures are interesting. The 288 cuttings in 1942-43 yielded half as much again as the 288 buddings, and the difference is significant at the 1 per cent. point. Unfortunately, there were slight differences in planting dates which give a slight bias in favour of the cuttings on age. The 36 sub-plots of each treatment were planted as follows:

	Sept. 1937	Dec. 1937	May 1938
Cuttings	27	3	6
Buddings	—	25	11

The differences arose from technical difficulties in the nursery, and although they seem small in comparison with the differences in yield, they must at this early stage be taken into account in interpretation of the *statistical* significance.

Furthermore, the broad comparison of all cuttings with all buddings, though as much as can be done on one good season's figures, is clearly not calculated to bring out all the differences that may exist. Cuttings and buddings will have to be compared within each clone and on larger total yields before conclusions can be drawn.

The chupon blocks gave only 82 per cent. of the yield of the fan blocks, but this difference is not significant, and having regard to the big differences between blocks it cannot be said at present that there is any evidence at all of differences in yielding power between chupon and fan material.

From the strictly practical viewpoint we might partially discount the age differences as a reflection of the greater difficulties experienced in the nurseries in preparing the requisite numbers of certain types of trees, notably chupon buddings. Since for ease of propagation and establishment we prefer fan cuttings to any other type of tree, it is at least pleasing to find no indication of inferiority in that type. The order of performance of the four types of trees tested was:

1. Fan cuttings, contributing 33 per cent. of the total yield
2. Chupon cuttings, " 26 per cent. of the total yield
3. Fan buds, " 22 per cent. of the total yield
4. Chupon buds, " 19 per cent. of the total yield

A considerable part of the difference will probably disappear as the trees age.

Experiment CRB. 2 (1941-43)

Treatment. The growth of the permanent shade in this planting, though not very good, has been distinctly better than in CRB. 1, and the growth of the cacao has also been better. The dry seasons of 1941 and 1942 were in the third and fourth years from planting, and there were still a lot of bananas in the field which seemed to help the young trees to tide over.

The trees were given a basket of pen manure and 1 lb. sulphate of potash in January 1941, and a further 1 lb. sulphate of potash in March 1942. No manures were applied in 1943.

Composition. The composition of the planting with respect to age is shown in Table V. There was a complete stand in May 1939, and losses in the two years following were very few, represented by the 8 supplies planted in 1940-42. The 12 trees missing in the 1942-43 season were probably casualties due mostly to cacao beetle, the effects of which were accentuated by the 1942 drought. Supplies and blanks are fairly evenly distributed over the clones, though I.C.S. 7 has more than a fair share.

The age differences are less than the table suggests, because the earliest plantings were in November 1938 and as noted above the stand was complete by May 1939. As the intervening months included the dry season, the delayed trees were very little handicapped. Of the 576 trees in the experiment, 556 (97 per cent.) were "originals". Heterogeneity in age is therefore appreciably less than in CRB. 1.

Yields. The first recorded picking was in June 1941, but this and an August picking were excluded from the crop year 1941-42, which was calculated as in CRB. 1 from 1st September 1941. On the other hand, for convenience a very small picking in October 1942 was added to the 1941-42 crop. There were no more pods before the end of the calendar year, and the 1942-43 crop in this case is that from 1st January to 31st August 1942. Yields for 1942-43, grouped by sub-plots, are given in Table VI, and yields for the two years in less detail in Table VII.

The pod values again reflect the conditions under which the crops matured, the very low average of 11.2 pods to 1 lb. in 1941-42 being undoubtedly due very largely to the dry season. It is noticeable, however, that even in the better season these clones have not approached the parental values as nearly as the older ones in CRB. 1, and it seems possible that in early bearing clones like these there is a general tendency for pod value to be low in the early years.

The average yield per picket for the whole planting in 1942-43 was 1.21 lb. dry cacao, equivalent to 367 lb. per acre, with the best clone (I.C.S. 1) averaging 1.97 lb. per picket or 591 lb. per acre. In both years CRB. 2 has yielded slightly more cacao than CRB. 1, in spite of being a year younger. This result is clearly due in large part to the more uniform performance of the clones, only I.C.S. 7 being as far below expectation as the three poor clones of CRB. 1.

That better conditions are also a factor in the result is indicated by the figures for I.C.S. 1, the only clone occurring in both sets. The 591 lb. per acre in CRB. 2 is not as far behind the 651 lb. in CRB. 1 as would be expected for a year's difference in age. The appearance of the field also suggests that conditions are in some way better in CRB. 2 than in CRB. 1, but it is hard to say whether the difference lies chiefly in better soil or in a better technique of establishment.

Analysis. The statistical analysis of the 1942-43 figures (by H. Doggett) shows significant differences between clones and propagation treatments but in this experiment there is no significant difference between blocks, which is a sign of more uniform soil conditions than prevail in CRB. 1.

The order of the clones from highest yielder to lowest was 1, 45, 16, 22, 53, 7. I.C.S. 1 performed significantly better than any other clone except I.C.S. 45, and I.C.S. 45 significantly better than I.C.S. 22 and 53. There is no significant difference between the yields of 1 and 45, between 45 and 16, or within the group 16, 22, 53. I.C.S. 7 was inferior in performance to every other clone in the set, with a very high degree of significance.

The clone order in 1941-42 was 45, 16, 1, 53, 22, 7, with both 45 and 16 yielding more than twice as much cacao as 1. The changes in order are due to particularly steep increases of yield by I.C.S. 1 and I.C.S. 22. The year 1941-42 being abnormal, no special importance can be attached

Table V.

COMPOSITION OF CRB. 2 IN CROP YEAR 1942-43

Clone	Type	Planted 1938	Planted 1939	Supplies of 1940-42	Missing
1	Buds	22	26	—	—
	Cuttings	40	7	1	—
7	Buds	22	24	—	2
	Cuttings	40	2	2	4
16	Buds	24	24	—	—
	Cuttings	33	14	1	—
22	Buds	20	25	1	2
	Cuttings	44	1	1	2
45	Buds	22	24	2	—
	Cuttings	45	1	—	2
53	Buds	24	24	—	—
	Cuttings	48	—	—	—

Table VII

YIELDS AND POD VALUES IN CRB. 2, 1941-43

Crop Year		ICS 1	ICS 7	ICS 16	ICS 22	ICS 45	ICS 53	Total
1941-42	Healthy pods	261	15	511	143	716	258	1904
	Kilos wet cacao	27.178	2.171	63.197	15.366	64.477	20.423	192.812
	Pod value	10.9	7.8	9.2	10.5	12.6	14.3	11.2
1942-43	Healthy pods	1609	96	1050	910	1421	925	6011
	Kilos wet cacao	215.092	13.862	150.296	109.562	199.346	106.977	795.135
	Pod value	8.5	7.8	7.9	9.4	8.1	9.8	8.6
Aggregate 1941-43	Healthy pods	1870	111	1561	1053	2137	1183	7915
	Kilos wet cacao	242.270	16.033	213.493	124.928	263.823	127.400	987.947
Parental pod values		6.3	6.3	6.0	6.5	6.0	6.5	

Table VI
EXPERIMENT CRB. 2 **CROP YEAR 1942-43** **AGE OF FIELD 4 YEARS**

Yields in pods and in grammes wet cacao. The number of healthy pods from each sub-plot is given in light type, followed by the number of diseased pods in italics and within brackets. Heavy figures show the weight of wet cacao from the healthy pods.
 B—buddings, C—cuttings.

	ICS 1		ICS 7		ICS 16		ICS 22		ICS 45		ICS 53		Totals for buddings	Totals for cuttings	Totals for blocks
	B	C	B	C	B	C	B	C	B	C	B	C			
Block 1 Fan	118 (9) 15,582	168 (10) 23,893	7 1,323	24 (8) 3,383	93 (20) 14,217	110 (24) 15,678	72 (7) 9,536	176 (26) 21,983	79 (5) 11,639	102 (6) 14,895	59 (11) 8,086	136 (28) 16,560	428 (52) 60,383	716 (102) 96,392	1144 (154) 156,775
Block 2 Fan	117 (8) 15,613	155 (4) 21,059	10 (2) 1,391	14 (7) 1,795	79 (10) 11,849	61 (4) 8,607	12 (2) 1,584	23 (4) 2,683	86 (5) 12,609	118 (1) 17,720	61 (3) 6,629	51 (7) 5,742	365 (40) 49,666	422 (24) 57,606	787 (64) 107,272
Block 3 Chupon	61 (2) 8,734	75 (2) 11,421	1 190	1 (1) 100	56 (8) 7,505	73 (18) 10,623	18 (6) 1,898	145 (23) 16,824	68 (5) 10,092	193 (8) 25,982	30 3,424	116 (7) 11,750	234 (27) 31,843	613 (59) 76,700	837 (80) 108,543
Block 4 Fan	137 (3) 17,923	191 (16) 25,280	— (1) nil	14 (1) 1,943	93 (10) 12,544	148 (25) 19,109	74 (5) 7,772	78 (8) 8,865	141 (7) 17,379	136 (15) 16,831	75 (1) 8,106	109 (16) 11,317	520 (27) 63,715	676 (84) 83,345	1196 (71) 147,060
Block 5 Chupon	98 (1) 13,024	195 (8) 25,682	5 860	3 485	73 (8) 10,613	80 (2) 12,657	100 (7) 12,860	100 (14) 11,707	169 (3) 23,346	139 (5) 21,225	37 (3) 4,774	110 (11) 13,108	482 (35) 65,477	627 (10) 84,864	1109 (75) 150,341
Block 6 Chupon	145 (11) 18,141	149 (6) 18,740	13 (1) 1,752	4 (3) 640	110 (6) 15,778	74 (2) 11,121	22 (1) 2,877	90 (7) 10,973	78 11,770	112 (4) 15,867	49 (5) 6,223	92 (4) 11,267	417 (24) 56,536	521 (26) 68,608	938 (50) 125,144
Totals	676 (17) 89,017	933 (46) 126,075	36 (4) 5,516	60 (17) 8,346	504 (62) 72,501	546 (75) 77,795	298 (38) 36,527	612 (82) 73,035	621 (25) 86,826	800 (42) 112,520	311 (23) 37,233	614 (73) 69,744	2446 (190) 327,620	3565 (335) 467,515	6011 (534) 795,135
	1609 (93) 215,092		96 (21) 13,862		1050 (137) 150,296		910 (120) 109,562		1421 (67) 199,346		925 (96) 106,977				Average pod value 8.6

to the change, and the trees are still young enough to show further changes of order before it is safe to place these clones in order of merit.

The performance of I.C.S. 45, however, calls for comment. At 3 years old, and in a bad year at that, it yielded at a rate of 178 lb. per acre, and at 4 years old more than trebled that yield with 548 lb. The circumstance making this result particularly noteworthy is that I.C.S. 45 is a Criollo cacao, believed to be of Nicaraguan origin, and belonging to a group generally rated as delicate and low-yielding. If it maintains anything like its present promise, this clone will be one of the most valuable selections in the series, at the high quality end.

The comparison of *propagation methods* is inconclusive for the same reason as in CRB. 1. In 1942-43 the cuttings gave 43 per cent. more cacao than the buddings, and the difference of 140 kilos is highly significant statistically, but possibly attributable to an age bias in favour of the cuttings.

The order of performance of the four types of trees, with their percentage contribution to the total yield is:

Fan cuttings	..	..	29.9
Chupon cuttings	..	..	29.0
Fan buddings	..	..	21.7
Chupon buddings	..	..	19.4

and the only comment thereon is the same as that for CRB. 1—that there is so far no indication that the most easily propagated fan cuttings are any less productive than the other types of material.

Experiment CRB. 3 (1941-43)

Treatment. No special treatment was needed in this planting beyond supplying and regulation of shade. The dry years hit these trees in their second and third years, before they were well established, but losses were not unduly severe. The trees were given a basket of pen manure and 1 lb. sulphate of potash in January 1941 and a further 1 lb. sulphate of potash in March 1942. No manures were applied in 1943.

Composition. The composition of the planting with respect to age is shown in Table VIII. Of the 576 trees in the experiment 502 (87 per cent.) were "originals", nearly three years old, at the beginning of the crop year 1942-43. Twenty-one gaps supplied in 1940 were the normal casualties to be expected in any planting, but 53 trees died in 1941 and 1942, and this rather high casualty rate is largely ascribable to beetle attack accentuated by the severe dry seasons. I.C.S. 2 is notably more susceptible in this respect than the other clones, and it and I.C.S. 12 between them account for 49 of the total 74 deaths. Over the rest, the casualty rate is only 6 per cent. for the first three years after planting, in spite of the two unfavourable years included.

Yields. Pickings totalling nearly 50 kilos were recorded in 1942, nearly all in July, but these have not been added to the crop year figures for 1942-43 which in fact cover only the period 1st January to 31st August 1943. The yields for the crop year, grouped by sub-plots, are given in Table IX.

The average yield per picket for the whole planting was 0.78 lb., equivalent to 231 lb. per acre, with the best clone (again I.C.S. 1) averaging

Table VIII

COMPOSITION OF CRB. 3 IN CROP YEAR 1942-43

Clone	Type	Planted 1939	Supplies of 1940-41	Supplies of 1942	Missing
1	Buds	44	—	1	3
	Cuttings	46	1	—	1
2	Buds	32	11	4	1
	Cuttings	31	4	2	11
9	Buds	45	2	—	1
	Cuttings	43	4	—	1
12	Buds	40	1	5	2
	Cuttings	40	3	4	1
60	Buds	41	3	—	4
	Cuttings	48	—	—	—
98	Buds	45	2	1	—
	Cuttings	47	1	—	—

EXPERIMENT CRB. 3

Table IX

CROP YEAR 1942-43

AGE OF FIELD 3 YEARS

Yields in pods and in grammes wet cacao. The number of healthy pods from each subplot is given in light type, followed by the number of diseased pods in italics and within brackets. Heavy figures show the weight of wet cacao from the healthy pods.
B—buddings, C—cuttings.

	ICS 1		ICS 2		ICS 9		ICS 12		ICS 60		ICS 98		Totals for buddings		Totals for cuttings		Totals for blocks	
	B	C	B	C	B	C	B	C	B	C	B	C						
Block 1 ...	55 (3) 7,439	97 (12) 14,196	24 (2) 4,178	20 — 2,360	21 — 2,865	45 (1) 5,555	37 (3) 5,260	31 (7) 4,080	66 (3) 11,231	77 (7) 13,769	48 (1) 4,815	174 (4) 16,172	251 (12) 35,788	444 (31) 56,132	695 (43) 91,920			
Block 2 ...	48 (3) 6,573	72 (7) 10,028	42 — 5,614	40 (11) 6,108	29 (1) 4,300	17 — 2,545	66 (3) 8,595	33 (2) 4,631	30 (6) 4,564	137 (24) 22,594	8 — 900	140 (6) 13,465	223 (13) 30,546	439 (50) 59,371	662 (63) 89,917			
Block 3 ...	49 (10) 7,274	113 (8) 14,650	10 — 1,532	52 (1) 5,842	42 (1) 5,254	63 (3) 8,067	53 (10) 5,971	49 (10) 7,152	18 (2) 3,254	44 (7) 8,246	29 (1) 3,165	125 (12) 12,053	191 (24) 26,450	446 (41) 56,010	637 (65) 82,460			
Block 4 ...	53 (4) 6,351	110 (7) 13,052	36 (4) 4,022	60 (13) 8,107	4 — 437	3 — 430	26 (2) 3,316	42 (1) 5,085	54 (5) 8,426	112 (15) 17,274	6 — 638	104 (2) 8,821	179 (15) 23,190	431 (38) 52,769	610 (53) 75,959			
Block 5 ...	60 (7) 8,023	74 (2) 10,350	26 (1) 4,306	61 (3) 7,462	16 — 2,135	5 — 740	45 (7) 6,162	48 (3) 6,496	49 (8) 6,809	77 (12) 12,272	96 (4) 9,614	68 (2) 5,933	292 (27) 37,049	333 (22) 43,253	625 (49) 80,302			
Block 6 ...	56 (6) 7,602	159 (10) 22,916	3 — 482	37 (2) 4,822	2 — 320	30 (1) 3,535	33 (5) 4,679	62 (1) 8,387	35 (7) 5,971	65 (3) 10,749	73 (2) 7,478	77 (3) 6,802	202 (20) 26,532	430 (20) 57,211	632 (40) 83,743			
Totals ...	321 (33) 43,262	625 (46) 85,192	141 (7) 20,134	270 (30) 34,701	114 (2) 15,311	163 (5) 20,872	260 (30) 33,983	265 (24) 35,831	252 (31) 40,255	512 (68) 84,904	260 (8) 26,610	688 (29) 63,246	1338 (111) 179,555	2523 (202) 324,746	3861 (313) 504,301			
	946 (79) 128,454		411 (37) 54,835		277 (7) 36,183		525 (54) 69,814		764 (99) 125,159		948 (37) 89,856		Average pod value 8.7					

1.18 lb. per picket or 354 lb. per acre. The difference between the average and the best is less than in either CRB. 1 or CRB. 2, reflecting the fact that in CRB. 3 there are no clones so conspicuously poor as the poorest in the earlier sets.

Analysis. The statistical analysis was carried out (by H. Doggett) for the sake of completeness of record, though it is obvious that few conclusions may legitimately be drawn from the performance of trees so young.

The differences *between blocks* are even less than in CRB. 2, and statistically insignificant.

The *order of the clones* from highest yielder to lowest is 1, 60, 98, 12, 2, 9, without any marked division into two or more groups. I.C.S. 1 and 60 both performed significantly better than I.C.S. 12, 2, 9, but not significantly better than 98, whilst I.C.S. 98 is significantly better than 9 but nothing else.

The comparison of *propagation methods* is limited in this experiment to cuttings v. buddings, as all the material used was fan type. The 145 kilos difference in yield between cuttings and buddings is far above the 65.5 kilos that would be significant at the 1 per cent. point, and this is interesting because both were planted between August and November in 1939. There is in this experiment much less bias in favour of the cuttings on account of age, than in CRB. 1 and CRB. 2, yet every clone has yielded more on its own roots than on seedling root-stocks as three-year old trees.

Experiment CRB. 4 (1941-43)

Planting. Seven missing sub-plots were filled in July 1941 and at the same time 49 supplies were put in to make good losses in the 1941 dry season.

Manuring. The trees were given a basket of pen manure and 1 lb. sulphate of potash in January 1941 and another 1 lb. sulphate of potash in 1942.

Yields. Pickings were recorded in January, April, June, July and August 1943, though the oldest trees were not three years old until July. All the clones gave some cacao showing that the self-compatible clones selected for this set are all early bearers. The circumstances do not warrant analysis of the figures, but they are as follows:

I.C.S. 1	....	....	51,174 gms.
44	....	....	22,061 "
55	....	....	11,841 "
70	....	....	22,585 "
91	....	....	16,932 "
95	....	....	53,024 "

Total 177,617 gms.

The total is equivalent to 81 lb. per acre.

Experiment CRB. 5 (1941-43)

Planting. Thirteen sub-plots had to be omitted from the general planting in October 1940, and these were completed in June 1941, and at the same time eighty-seven supplies were put in to make good the losses of the dry season.

Manuring. The trees were given a basket of pen manure and $\frac{1}{2}$ lb. sulphate of potash in January 1941, and a further application of pen manure with a heavier dressing of potash in March, 1942.

Further Treatment. Some trouble was expected in establishing these Criollo clones, and the dry seasons of 1941 and 1942 ensured that such expectations were realized. Several of the clones are highly susceptible to beetle attack and some quite large trees have been completely ringed and killed. By mischance it happened also that this planting included a largish patch of poor soil, on which neither ground shade nor permanent shade will flourish and consequently continuous attention is necessary to prevent the encroachment of grass. Nevertheless, some parts of the planting look quite well, and the usual weeding, supplying, and control of banana shade are being continued. There had been no crop record up to the end of the period under review.

Experiment CRB. 6 (1941-43)

Planting. The planting of this experiment has unfortunately been very irregular, due to difficulties in the nursery. The trouble was caused by the decision to include chupon material in this experiment, as in CRB. 1 and CRB. 2. The cutting back of the chupon stools in the nursery to provide the necessary material was followed by a severe dry spell in which many of the stools were lost and those remaining alive were checked. As a result, only 35 of the 72 sub-plots were planted during August and September 1941, when the whole set should have been completed. Another 28 were planted in July 1942, and 3 in 1943, leaving 6 sub-plots still blank.

The comparison between chupon and fan material will probably never be valid in this experiment, but the planting will not be valueless on that account. Actually the three blocks planted with fan material were almost completely filled in August and September 1941, six missing sub-plots being completed in July 1942, and the heterogeneity in age occurs almost entirely in the three chupon blocks. At the worst, therefore, we have 48 trees of each clone under comparison, scattered in three sets of randomized blocks with no more variation in age than occurs in others of this series of experiments, and from them we may hope to get the most important of the information sought.

Ground-shade conditions in this planting have been good throughout, and the trees suffered less from dry weather than some of the older ones.

A basket of pen manure and $\frac{1}{2}$ lb. sulphate of potash were applied to each tree in March 1942.

Experiment CRB. 7 (1941-43)

This simple observation plot is being gradually completed as material is available. Since there is no intention of making statistical comparisons of clonal behaviour in this experiment, differences in age do not matter much, and precedence in propagation has had to go to supplies for the earlier plantings. Several of the clones planted in 1940 are in bearing, and observations of their behaviour are being recorded.

Experiment CRB. 8 (1941-43)

This experiment, which was completely planted by the end of 1939 has perforce been somewhat neglected on account of the labour shortage that has prevailed since 1941. Whenever facilities allow, the trees will be recorded, but for the present it is no disadvantage to allow them to come into fuller bearing before detailed observations are made.

Experiment CRB. 9

This, which has not previously been described, is another simple observation plot, planted like CRB. 7 to obtain qualitative information about clones which cannot immediately be included in quantitative experiments. It is situated on "chocolate" soil at San Juan Estate, Gran Couva, and consists of 500 trees forming five complete sets of the clones I.C.S. 1-100.

The site is a long narrow strip between a path-way and a steep hillside, and allows 50 rows of 10 trees running roughly at right angles to the path. The trees are planted in sequence from I.C.S. 1 to I.C.S. 100 without any scatter, and the whole sequence is repeated five times. This arrangement is very convenient for the rapid location of any individual in a set, but less useful for the visual comparison of clones than the lay-out of the later planted CRB. 7. Experience suggests that it would have been better to plant two or three trees of each clone together, and have only two series instead of five.

The site was felled in 1937 and the first plants were put in in 1939, but for various reasons it has been impossible to complete all the sets until now. The plot is, however, now almost complete. All the trees are cuttings on their own roots. Many of the clones are in bearing, and are being recorded for us by Dr. A. L. Jolly of the Economics Department of the College, to whom grateful acknowledgment is due for his assistance.

Experiment CRB. 10

(By R. K. McKee)

This experiment, which is laid down at San Juan Estate, Gran Couva, is designed to give some comparison between I.C.S. clonal material and seedling progenies. The seedlings were obtained from open-pollinated pods collected in an isolated plot consisting entirely of cuttings of various I.C.S. clones. Thus it may be expected that these seedlings will have as desirable qualities as are possible in seedlings resulting from open pollination.

Pods were collected from cuttings of I.C.S. 1, I.C.S. 45 and I.C.S. 95, and 100 seedlings from each of these parents were raised. 100 cuttings of each of the above clones were planted for comparison.

Owing to the irregular and broken nature of the ground available, it was not possible to lay out a properly replicated statistical design. However, some replication is provided, the following planting order being used, starting from the S.E. corner. The labelling runs alternately up and down consecutive rows.

33 seedlings from I.C.S. 1
34 seedlings from I.C.S. 45
33 seedlings from I.C.S. 95
33 cuttings from I.C.S. 1
34 cuttings from I.C.S. 45
33 cuttings from I.C.S. 95

This is repeated 3 times, with the exception that in the second replication, there are 34 I.C.S. 1 seedlings and cuttings, and in the third replication, there are 34 I.C.S. 95 seedlings and cuttings.

The pickets are placed 14 feet apart, with immortelle shade trees planted 48 feet apart. The planting was carried out in November, 1941.

This experiment, as well as providing a comparison of cuttings and of good seedlings, will also show what type of progeny may be expected from open pollination in a plot consisting only of high yielding and otherwise desirable trees.

THE INCIDENCE OF CACAO BEETLE DAMAGE ON SOME I.C.S. CLONES PLANTED AT RIVER ESTATE

By R. K. McKee

The cacao beetle (*Steirastoma depressum* L.) is very prevalent on the recently planted fields at River Estate. This district is probably among the most severely infested in the island, so that although these results do not necessarily apply to other areas, it is improbable that worse damage will be encountered elsewhere.

In the various experimental plantings which have recently been laid down, many of the young plants have been severely attacked while some have been killed. It is found that damage is most severe on trees from the age of 3 to 5 years. The very young trees and trees over the age of 5 years, although attacked occasionally, are not subject to the same infestation. This is very probably

due to shading; the young trees have good ground cover, while by 5 years the canopy has begun to close. Damage is of two types, the relatively unimportant gnawing of the bark of the young twigs by the adult beetles and the burrowing of the larvae in the older parts of the tree. The larval (or "worm") stage hatches from an egg laid usually at the jorquette or at the junction of two branches. The larva burrows in the bark and may encircle the main stem, or a branch, which soon dries off. The presence of the larva may, however, be detected by the darkening of the bark and the exudation of mucilage and frass from the exit of the burrow (1). The young trees are regularly inspected and such larvae

as are detected are cut out; if this precaution were relaxed, mortality would be much higher. The cut area heals in a short time, but leaves a scar.

It was noticed in Field Experiment CRB. 1 that some clones appeared to be more severely attacked than others. A detailed survey was made to see if this was really so. The number and extent of the old scars on each tree was used as a measure of the severity of attack. No account was taken of the damage done by the adult beetles on the bark of the young twigs as this is of slight importance compared to the damage done by the larvae.

A scoring system was employed, the scores being as follows:

0. No damage
1. Slight damage
2. Moderate damage
3. Severe damage
4. Very severe damage
5. Dead or dying

In the last group were included such trees as were recorded as having been killed by beetle damage and which had been replaced. As a single larva can kill a small tree, if undetected, such a high score may not have been justified in all cases but there was no method of getting more precise data about trees already replaced.

The results are here analysed statistically. The experiment consists of a randomized block lay-out 6 blocks each of 6 plots; each plot contains 16 trees of one clone. The mean severity of attack for each plot was obtained by adding the scores and dividing by the number of trees (occasionally less than 16 owing to missing trees). This figure enabled the 6 clones in each block to be placed in order of severity of attack. The correct scores which should be applied to these original values (Table XX Statistical Tables, Fisher & Yates) (2) are as follows:

1st	2nd	3rd	4th	5th	6th
1.35	0.75	0.35	-0.35	-0.76	-1.35

These scores are expressed as deviations about a mean to simplify calculation. The total scores for each clone over the 6 blocks were as follows:

Order	Score
I.C.S. 8	4.56 Relatively free from
6	2.98 attack
1	1.19
3	0.2
4	-3.4
5	-5.51
	Severely attacked

In Table XI are given the estimate of severity of attack, the order of severity of attack and the corresponding score for each of the 6 clones over the 6 blocks from which the above totals were obtained.

Table XI

BLOCK \ C.				1	3	4	5	6	8
S.									
1	Estimated damage	...	...	0.75	0.69	1.80	1.69	0.625	0.44
	Order	...	...	4	3	6	5	2	1
	Score	...	...	-0.20	0.20	-1.27	-0.64	0.64	1.27
2	Estimated damage	...	...	0.5	0.5	0.625	1.31	0.44	0.44
	Order	...	...	3	3	5	6	1	1
	Score	...	...	0	0	-0.064	-1.27	-0.96	0.96
3	Estimated damage	...	...	0.375	1.125	0.69	2.06	0.375	0.69
	Order	...	...	1	5	3	6	1	3
	Score	...	...	0.96	-0.64	0	1.27	0.96	0
4	Estimated damage	...	...	0.625	0.125	1.69	1.078	0.31	0.19
	Order	...	...	4	1	6	5	3	2
	Score	...	...	-0.2	1.27	-1.27	-0.64	0.2	0.64
5	Estimated damage	...	...	0.19	1.625	0.625	0.625	0.31	0.31
	Order	...	...	1	6	4	4	2	2
	Score	...	...	1.27	-1.27	-0.42	-0.42	0.42	0.42
6	Estimated damage	...	...	0.69	0.375	0.4	3.00	0.5	0.31
	Order	...	...	5	2	3	6	4	1
	Score	...	...	-0.64	0.64	0.2	-1.27	-0.2	1.27
Total Scores				1.19	0.2	-3.4	-5.51	2.98	4.56

Table XII gives the analysis of variance using these scores.

Table XII

	S.S.	D.F.	Variance	F test
Total	24.04	35		
Variety	12.18	5	2.44	6.18
Error	11.86	30	0.395	

A value of $F=6.18$ is obtained. For a probability $P=0.01$, $F(n_1=5, n_2=30)=3.70$, so that there is a significant difference between the variety totals and the T test may be applied.

$$\text{S.E. of variety totals} = \sqrt{0.395 \times 6}$$

$$\begin{aligned} \text{Sig. difference} &= \sqrt{0.395 \times 6 \times 2 \times 2.042} \\ &\quad (n=30, P=0.05) \\ &= 4.44 \end{aligned}$$

I.C.S. 4 and I.C.S. 5 are severely attacked while I.C.S. 8 is only slightly attacked. I.C.S. 6, I.C.S. 1 and I.C.S. 3 occupy an intermediate position. If cuttings are to be planted in a beetle-infested area I.C.S. 5 and possibly I.C.S. 4 should be avoided, unless special precautions are taken to protect them.

Acknowledgment

My grateful acknowledgment is due to Mr. R. E. D. Baker, of the Imperial College of Tropical Agriculture, who originally suggested that the clones were unequally attacked by the cacao beetle.

References

- (1) Guppy, P. L. The Life History and Control of the Cacao Beetle. Circular No. 1. Board of Agriculture, Trinidad, 1911.
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SOME OBSERVATIONS ON I.C.S. CLONAL MATERIAL AT RIVER ESTATE

By R. K. MCKEE

Introduction. A series of observations on the botanical behaviour of young trees in Field Experiment CRB. 1 (Cheesman, 10th Ann. Rept. Cacao Res. 1940 Section A) was started in August 1940, since when weekly records have been made on leaf flush, flowering and wilting of young cherelles.

Previous observations of a similar nature, such as those of Pyke (2nd Ann. Rept. Cacao Res., 1932, p. 37) and McDonald (*ibid.* p. ii) have been made on seedling populations, and this is the first occasion on which a large block of clonally propagated material was available. Primary objects of the work, therefore, were to discover how young vegetatively propagated plants behave as a whole, what degree of variation may be expected within clones, and whether important differences can be detected between clones.

These observations cover the period from August 1940 to May 1942.

Material and Methods. The observations were made on one half of Field Experiment CRB 1, that is, on 288 trees, 48 of each of the six clones in the experiment. The trees are laid out in plots of 16, and in each plot half of the trees are cuttings while the other half are budded plants on seedling root stocks. These trees were planted between September 1937 and May 1938 so that the majority were slightly under 3 years old when the observations were started. There is some variation in age and size of the individual trees, not only owing to irregular growth but also owing to deaths and subsequent replacement. The observations were made on all the trees but in the estimates of number

of flowers produced and the number of cherelles set, the very young trees are not included in the analysis of the data.

The clones included are I.C.S. 1, 3, 4, 5, 6 and 8 of which 1, 6 and 8 are self-compatible while 3, 4 and 5 are self-incompatible.

Observations on flushing may be made in various ways. For instance, various branches of the tree may be marked and subjected to detailed examination and measurement in growth and length, etc. This intensive method has been employed by Humphries, E.C. (10th Ann. Rept. Cacao Res., p. 22), his results being published in this report. This method has the great advantage that, as a definite number or length is noted, the personal error is eliminated. The main disadvantage is that both the number of twigs per tree and the number of trees which can be examined are limited by the considerable time required for each observation.

On the other hand extensive observations can be made on flushing. Thus Pyke (*loc. cit.*) used a scoring system in which the intensity of the flush on each tree was recorded. As only one rapid observation is made, this method enables many more trees to be dealt with but much more depends on the skill of the person recording. With practice consistent results can be obtained.

In this work, it was necessary to determine as closely as possible, and purely for comparative purposes, the date on which the tree flushed. It was decided to employ the extensive method of observation, each tree being treated as a unit and the average condition of the whole tree noted. The most distinctive point in the flushing cycle is when the scale leaves of the bud open and the young

flush leaves start to expand. The date when each tree assumed this condition was recorded. It is often found that growth is not simultaneous on all the buds of the tree. In practice a tree was noted as starting to flush when at least a quarter of the buds were opening. Usually the majority of the buds on these trees opened in 1-3 consecutive weeks, though in this connection it must be remembered that the trees were not yet full grown, and that there might be greater variation in fully grown trees.

During the dry season flushing becomes very irregular and this method is difficult to apply. This difficulty is reflected in the variable results for this period.

From August 1941 to May 1942, record was also made on the weekly intensity of flush on each tree in Blocks 1, 2, 3, 4 of Expt. CRB 1. "Intensity" is a term difficult to define but it may be considered as a function of the proportion of twigs which are producing new flush leaves and of the amount of flush each is producing. A scoring system was used in recording the intensity, the following scores being allotted.

Score 0—No young flush leaves present.

1—A few flush leaves present.

2—Less than half the tree flushing.

3—More than half the tree flushing.
(A normal flush)

4—A very strong flush.

5—An exceptionally strong flush.

A scoring system is also used in recording the number of flowers. An approximate count is made and the appropriate score is accorded to the tree. This can be done more quickly than can an accurate count, an important consideration as 288 trees were examined each week. Any loss in accuracy is more than compensated by the increase in the number of trees which can be recorded. A scoring system also enables some allowance to be made for the size of the individual trees.

The following range was employed in scoring, only open flowers being counted.

Score 0—No flowers

1—1-6 flowers

2—7-24 "

3—25-54 "

4—55-96 "

5—96- "

Observations on Wilted Cherelles.—Each week such cherelles as had wilted and turned yellow, were removed from the tree and counted. This method does not include those cherelles which had wilted and which had fallen off before counting—a fraction which may average as much as 10 per cent. of the total (Humphries, E.C., private communication). It is assumed that about the same proportion will be lost from each clone in this way so that the relative values will be correct even if the absolute values are too low. Neglecting this lost fraction, the total number of cherelles set by any tree is obtained by adding the number of wilted cherelles and the number of pods matured.

These counts of wilted cherelles were discontinued after one year's observations had been obtained.

Description of Data.—The data have been condensed and tabulated to show:

(1) Seasonal variation in the behaviour of the trees.

(2) The difference between the individual clones.

Flushing.—In Fig. 1 are given the dates of flushing of the individual trees of the clone I.C.S. 1. As explained above, the date marked is that of the start of the flush. If the same tree is recorded as starting on two or more successive weeks it indicates that not all the buds started on the same week. The number of flushes marked is no measure of the intensity of the flush but only of whether it is spread out or not. The flushing records for the other five clones are similar.

In Fig. 2 the number of trees flushing on any week is recorded. In this, if a tree starts in 2 weeks it is counted as $\frac{1}{2}$ on each week etc. This graph indicates that all the trees flush at about the same time, especially during the wet season. In any clone there is some variation from tree to tree but the flushing curves of Fig. 2 show definite peaks when the majority of the trees are flushing. During the wet season these flushing peaks follow at intervals of 7 to 8 weeks and the trees of any one clone keep in step with each other. In the dry season irregularities become more marked. This is due partly to the difficulty of recording, as the young flush leaves often wither before they reach maturity. Buds also tend to open individually so that it is difficult to say whether the tree as a whole is flushing or not. In some cases when the young leaves were withered, the branch flushed again, leading to almost continuous flushing. This is to be regarded as a pathological condition brought about by the severe dry seasons of 1941 and 1942, and the rather light shading of the trees in this particular experiment.

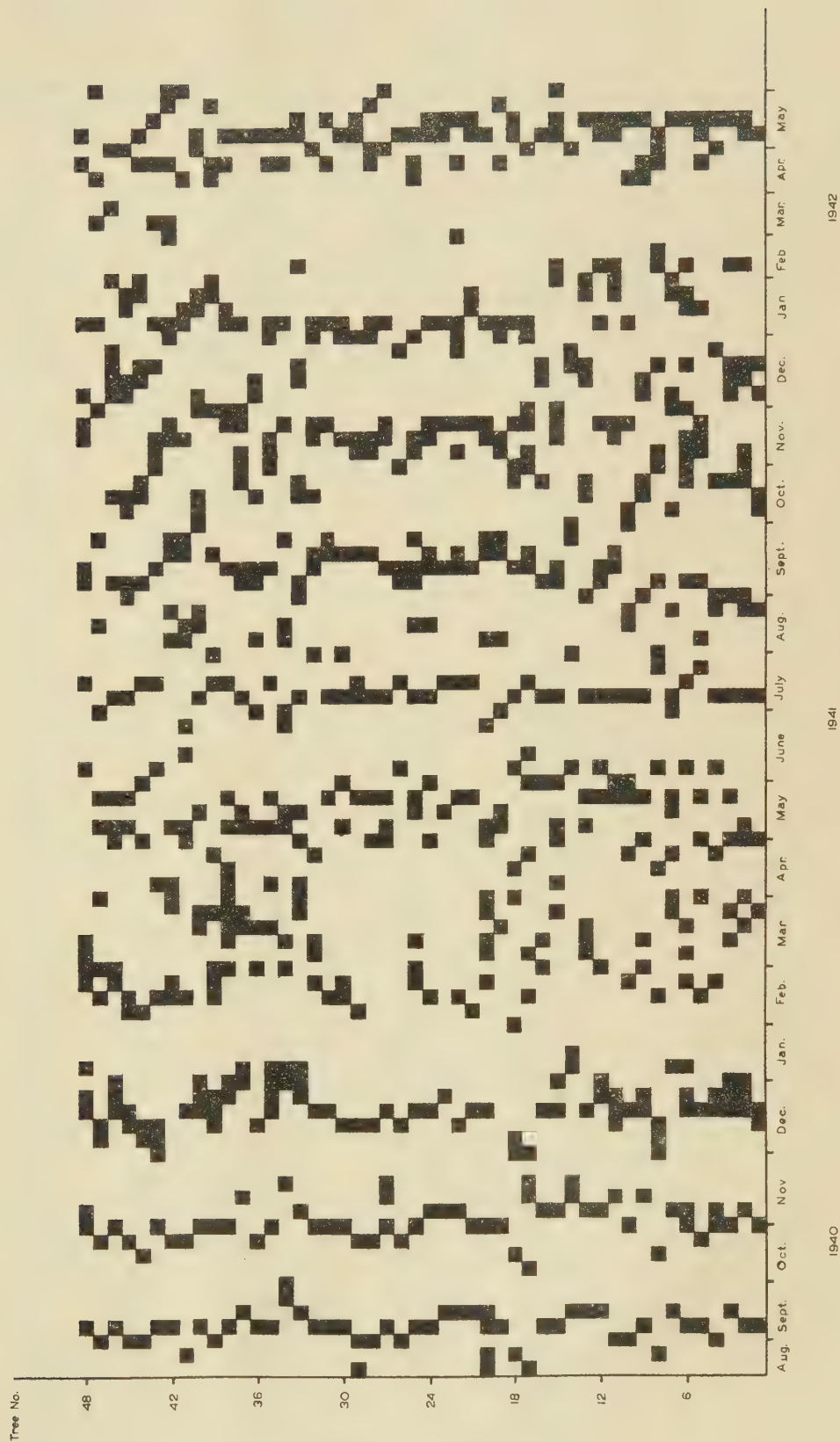
This irregularity of flushing in the dry season is more marked in some clones than in others. Thus I.C.S. 5 shows quite definite peaks even in the dry season while I.C.S. 4 is very irregular.

It will be noted, in Fig. 1, that a tree which flushes later or earlier than the average for its clone in one flush will usually do the same in the succeeding flush. That this behaviour is determined by the inherent condition of the tree and not by any "earliness" or "lateness" of the local environmental conditions is indicated by the fact that, after the rhythm of flushing had been broken by the irregular behaviour during the dry season, some trees which had been early flushers became late flushers and *vice versa*. This may also be caused by a tree missing a flush or putting in an extra flush as happens occasionally.

Fig. 2 indicates that not only do the trees of any clone flush together but also that the various clones flush together. There are, however, slight differences between the various clones, most markedly between I.C.S. 1 and I.C.S. 5. Taking a mean for 48 trees in each clone, over 7 flushes

FIG. 1

CLONE ICS 1



NUMBER OF TREES FLUSHING

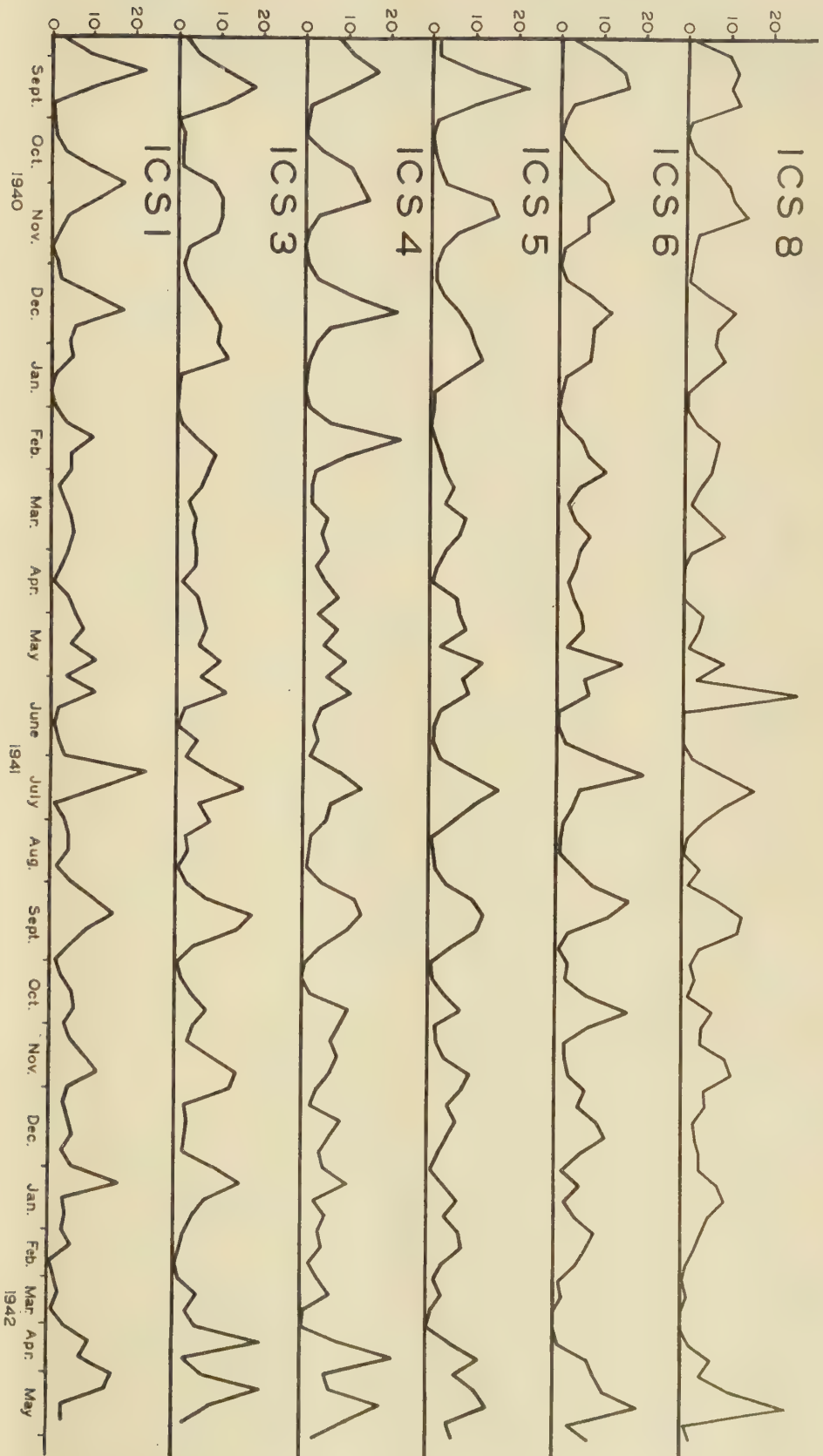
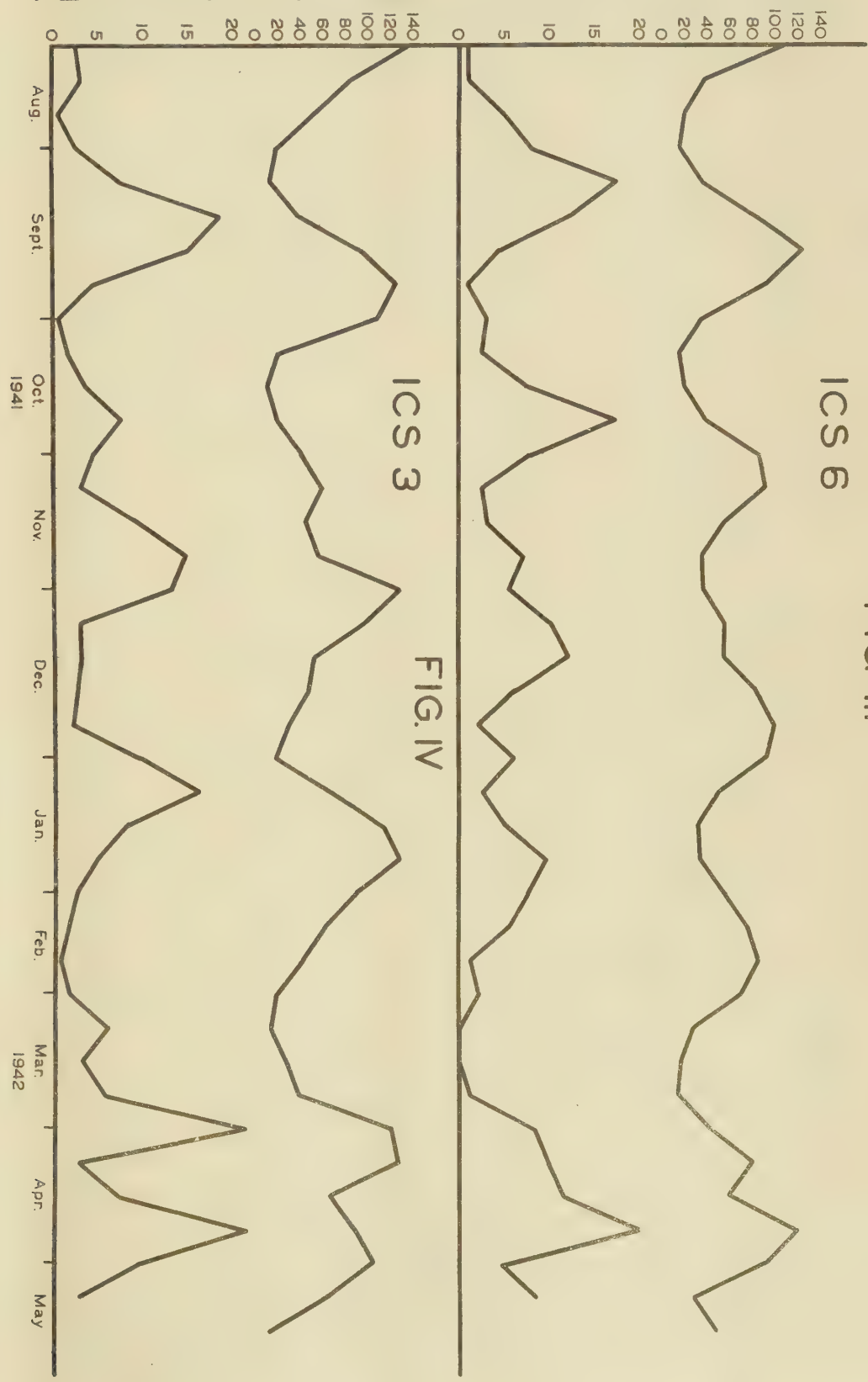
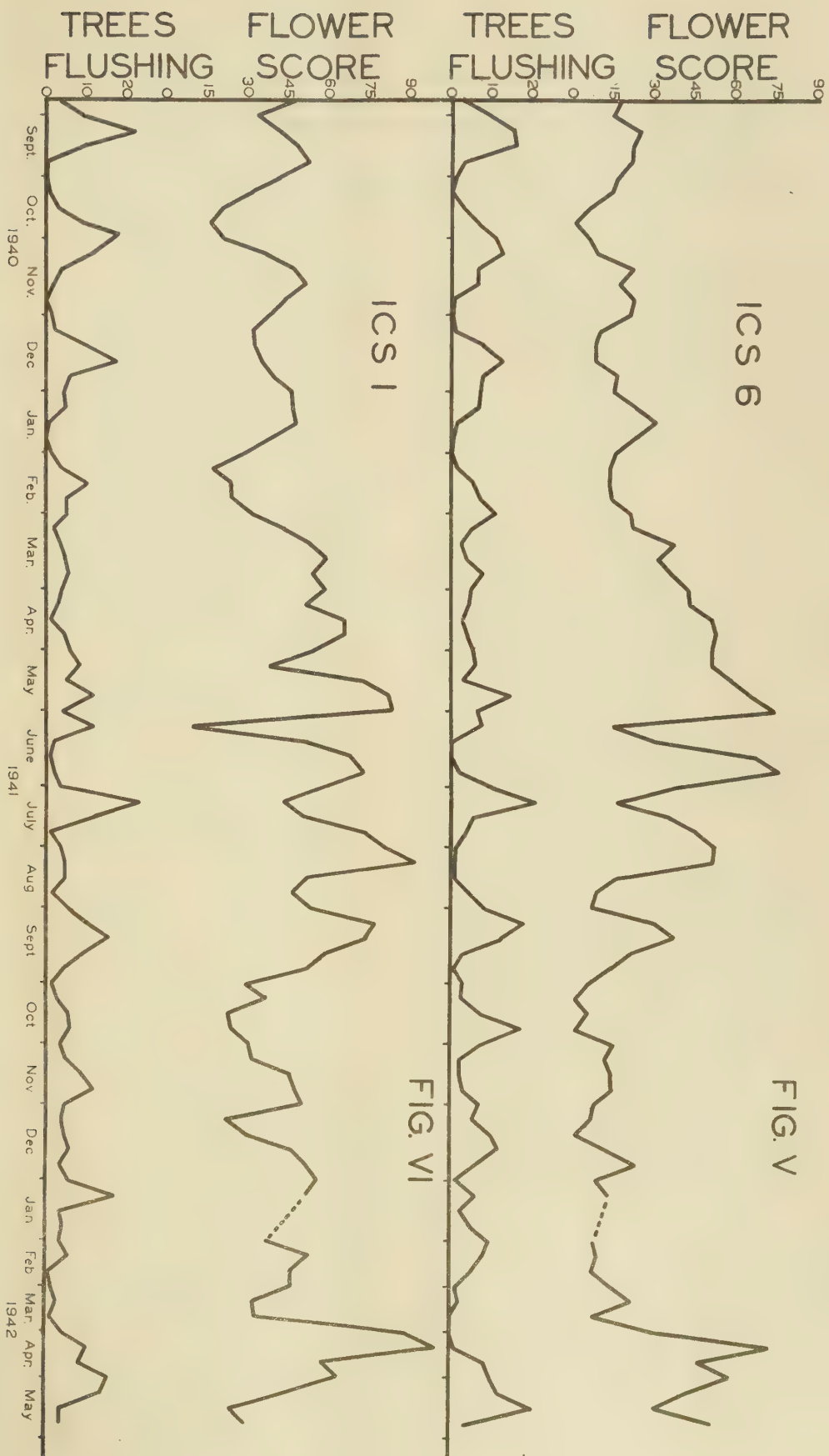


FIG. 11

TREES FLUSHING "Σ FLUSH" TREES FLUSHING "Σ FLUSH"





I.C.S. 5 takes on the average 0.36 weeks longer to flush than I.C.S. 1. This is only a small difference but it is cumulative and leads to a difference in average flushing date of 2.5 weeks after 7 flushes. Against this, there is the fact that, as stated above, the various clones flush nearly on the same date. A possible explanation of this is that all trees are induced to flush by the first rains of the wet season, which, as it were, phases them correctly again. This suggestion is supported by the marked flush recorded at the beginning of the wet season.

In Figs. 3 and 4, the flushing as recorded by intensity of flush is compared with the "buds starting" curve for two clones. There is good agreement between the two sets of curves, with a lag of about 2 weeks in the intensity curve. "Intensity of flush" was, in practice, found easier to estimate than the time when the "buds started" and it is suggested that it would be the more suitable method for any future investigation.

To compare the intensity of flushing of the various clones, the clonal scores for each week were added up for two periods—7/8/41 to 2/1/42 and 9/1/42 to 8/6/42. The clones were placed in order of intensity and appropriate scores accorded from Fisher and Yates (Statist. Tables, Table XX, Scores for Ordinal Data). An analysis of variance was made using the 4 blocks, the final results being given in Table XIII.

Table XIII

7/8/41 to 2/1/42. Wet season			
Clone	Score		
I.C.S. 6	2.12		
5	2.11	More vigorous flushes	Significant difference between scores = 3.88 ($P=0.05$)
1	2.10		
3	0.23		
4	-3.18	Less vigorous flushes	= 5.18 ($P=0.01$)
8	-3.88		
9/1/42 to 8/6/42. Dry season			
3	4.01	More vigorous flushes	Significant difference between scores = 2.97 ($P=0.05$)
4	1.91		
5	0.88		
6	-0.44	Less vigorous flushes	= 3.97 ($P=0.01$)
1	-1.28		
8	-5.08		

There is considerable variation in the order of the clones in the two seasons, and more study would be required before definite conclusions could be reached. I.C.S. 8 is definitely the least vigorous flusher. This is not to be taken to mean that I.C.S. 8 grows less vigorously than the other clones. It is a sturdy clone and over the two seasons 1940-41/2 produced more cacao than any of the other 5 clones in this experiment.

Flowering.—Figs. 5 and 6 show the weekly flower production for 2 of the six clones, the other four being similar. The flushing records for these clones are included on the same graphs. The number of flowers produced varies in a periodic manner, the peaks in flowering following at intervals very similar to those between the peaks in flushing. On the average, the flowering peak is 2.5 weeks after the flushing peak, where flushing is recorded by the opening of the young buds. After 2.5 week interval the young flush leaves have expanded but are not yet hardened and mature.

This apparent relationship between the peaks in flushing and in flowering was tested by the χ^2 test for the wet season when the peaks are well marked. The calculation is shown in Table XIV where the dates of the flushing peaks have all been retarded by 2.5 weeks. The mean dates for the six clones are used.

Thus it may be assumed that the differences between the dates of flushings and flowering peaks are no greater than may be reasonably expected from random variation, and that there is a relationship between the number of flowers produced and the flushing of the tree.

During the dry season flower production is very irregular, with, however, similar peak periods which correspond roughly to the peaks in flushing. Agreement between the two is less marked than in the wet season but this is to be expected from the difficulty in recording flushing at this season.

In actual numbers, more flowers are produced during the dry than during the wet season, with a very marked peak at the beginning of the wet season.

In Tables XV and XVI the totals of flower scores produced by the various clones are given, Table XV including the period August 1940 to August 1941, and Table XVI the period September, 1941 to May, 1942.

Table XIV

Date of flowering peak in weeks from start of records	...	...	...	...	5.33	13.33	21.16	30.75	50.5
Date of flushing peak retarded by 2.5 weeks (m)	...	...	...	...	6.33	13.75	21.50	29.50	50.16
Difference (x)	...	...	...	...	1.0	0.42	0.34	1.25	0.34

$$\sum \left\{ \frac{x^2}{m} \right\} = 0.248 \text{ (when } n=1)$$

$$P > 0.5$$

Table XV

Clone No. Flower Score

I.C.S. 5	76.4	} High Significant difference between means = 11.5 (P=0.05) = 14.5 (P=0.01)
4	73.4	
3	66.0	
1	52.4	
8	48.0	} Low
6	33.0	

Table XVI

Clone No. Flower Score

I.C.S. 4	43.4	} High Significant difference between means = 5.7 (P=0.05) = 7.35 (P=0.01)
5	41.1	
8	39.4	
1	35.8	
3	33.9	} Low
6	15.3	

The order in which the clones may be placed agrees roughly for the two seasons, I.C.S. 4 and I.C.S. 5 producing large numbers of flowers, while I.C.S. 6 produces fewer flowers than the other clones. The difference between the clones is less pronounced in the second season, when also I.C.S. 3 and I.C.S. 8 have approximately interchanged the positions they had in the first season. I.C.S. 3, 4 and 5 are self incompatible clones, while I.C.S. 1, 6 and 8 are self-compatible. On the whole, these results confirm Cope's (Cope, F.W., 8th Ann. Rept. Cacao Res. 1938 p. 4) results which showed that self-incompatible seedling trees produced more flowers than self-compatible seedling trees.

Cherelle Wilt. Figs. 7 and 8 show the numbers of wilted cherelles removed each week from two of the six clones. Here again there are marked peaks occurring some time after the peaks in flowering, *i.e.*, about the same time as the flushing is maturing. These peaks vary in height, being much more marked in the wet than in the dry season, which is only to be expected as fewer cherelles are set during the dry season. The number of cherelles wilted depends partly on the total number of cherelles on the tree in that week and partly on a variety of external conditions and internal factors in the tree. The number of young cherelles present will depend on the flowering during the weeks immediately previous (provided conditions have been favourable for pollination) while Humphries (Humphries, E.C., page 23 in this Report) has shown that the maturing flush competes with the developing cherelles for the available supply of mineral nutriment. The position of the peak in wilting as shown in Figs. 7 and 8 agrees with both these hypotheses.

In Table XVII are given the total number of cherelles collected from each of the six clones, plus the number of pods matured *i.e.*, the total set for the year, excepting such cherelles as have fallen before counting.

Table XVII

Clone	No. of Cherelles set	Total set ÷ Flower estimate
ICS 1	1,685	31.9
3	695	10.5
4	548	7.5
5	331	4.3
6	592	17.9
8	1,465	30.5

Also included in the table is the ratio of the number of set and the estimate of flower production for each clone. This ratio is much higher for the self-compatible than for the self-incompatible clones. This again confirms Cope's findings (*loc. cit.*) for seedling trees.

Discussion. The most obvious feature in the behaviour of the cacao tree, as indicated by the observations, is the marked periodicity. The fact that the cacao tree produces periodic flushes of leaves and new wood has been known presumably as long as the crop has been cultivated but this periodicity also extends to the flowering of the tree and the wilting of the young cherelles. A direct relationship of cause and effect between flushing and flowering, or between flushing and wilting of cherelles cannot, however, be deduced without further study: for all these may be responses to some other factor, as yet undetermined.

It is unlikely that weather can be responsible for behaviour as regular as that recorded for these cacao trees during the wet season. In the dry season, the weather may be said to regulate flushing in that conditions are generally unsuitable. When the tree flushes it uses up material reserves, whether mineral, carbohydrate or other substances and in normal circumstances these must be accumulated before it flushes again. It is suggested that the minimum interval between flushes is determined by the time required in this process, although the actual date on which flushing occurs may be decided by some combination of weather conditions, as for instance, at the beginning of the wet season when there is usually a marked and uniform flush.

That other factors are also concerned is shown by some preliminary experiments in which early flushing of twigs was induced by stripping the leaves, a treatment which can hardly accelerate the accumulation of carbohydrate. This suggests that under normal circumstances, there is some factor connected with the leaves which inhibits flushing until reserves have been elaborated.

WILTED TREES
FLUSHING

CHERELLES
PER WEEK

TREES
FLUSHING

CHERELLES
PER WEEK

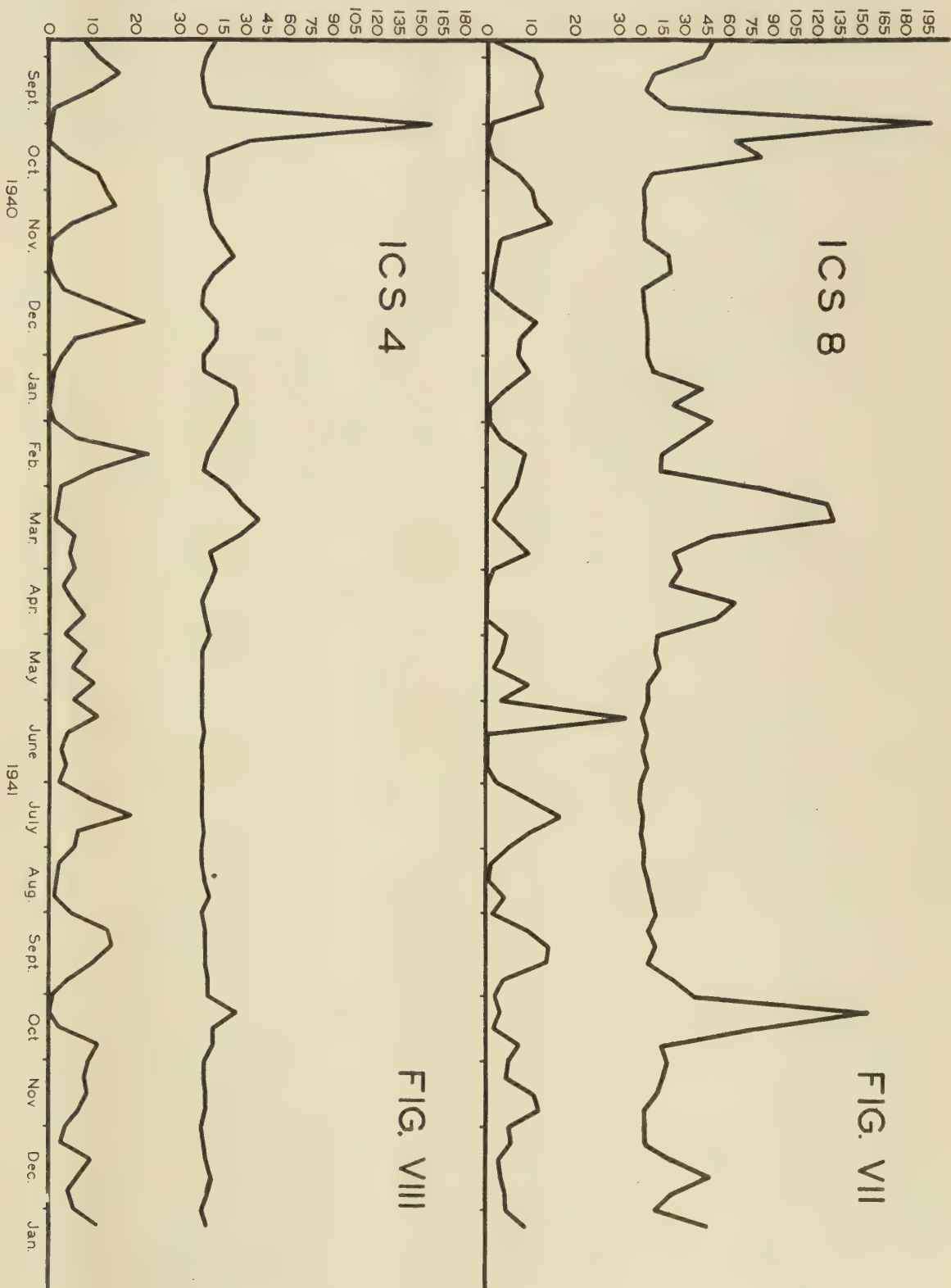


FIG. VII

ICS 8

FIG. VIII

ICS 4

In abnormal circumstances, such as when the leaves are stripped from a branch, or during a severe dry season or exposure to winds, it would appear that this inhibition is released and the normal rhythm of flushing is disturbed. New growth takes place before there is sufficient reserve material for the process. In such circumstances, flushes often recur at very short intervals, the leaves produced in successive flushes becoming smaller and smaller, while the growth in length per flush is also reduced. A tree in such a state is much weakened and notoriously susceptible to insect and fungal attack.

The importance of elucidating the internal and external factors which determine flushing, and the interrelationship between these factors, is obvious both from a scientific and from a purely practical point of view. It is hoped that the data presented in this paper, and the speculations concerning their interpretation will furnish a basis for further studies in this field.

Acknowledgment

My grateful acknowledgment is due to Professor E. E. Cheesman, who suggested that these general observations should be made.

B.—CHEMICAL AND ECOLOGICAL SECTION

THE CHEMICAL PROGRAMME, 1941-43

By F. HARDY

(1) Separate annual reports have not been issued for the years 1941, 1942 and 1943, so that this (eleventh) report comprises an account of the work accomplished by the Chemical Section during the last three-year period.

(2) Dr. H. F. Birch, who joined the staff as cacao biochemist in December, 1938, resigned his post in February, 1941; his contributions to cacao research have already been described in articles published in the Eighth, Ninth and Tenth Annual Reports.

(3) Since the beginning of 1941, the chief responsibility for researches in the Chemical Section has therefore fallen on Dr. E. C. Humphries, whose work during the three-year period under review has been mainly plant physiological and has concerned his further studies on cherelle wilt of cacao and especially new studies on the dormancy of cacao tree buds and on bud-bursting and leaf-flushing (*See References*).

(4) Concurrently, Dr. Humphries has continued the investigations on cacao tannins (begun by J. A. McDonald in 1936), and has recently announced some important results (*See References*).

(5) *Soil Aeration*.—In the meantime, further investigations on soil aspects of cacao ecology, mainly concerning soil aeration, have been carried out by two Post Graduate students of the College (Dr. H. Vine and Mr. H. A. Thompson), working under the writer's direction, and the results of their endeavours, abstracted from their respective dissertations, have been described by the writer in *Tropical Agriculture* (*See References*).

(6) These further cacao soil investigations have clearly shown that, at sites where downward drainage is impeded, either because of low-lying topography or because of natural soil imperviousness, waterlogging may continually reduce the degree of soil aeration beyond the toxic limit. The results have also demonstrated that this undesirable state of affairs obtains at many such sites in Trinidad cacao estates, even during a large part of the dry season, as well as for most of the wet season, and that persistent waterlogging may adversely affect subsoil aeration up to within a short distance of the actual ground surface. In consequence, the nutrition of the cacao tree often suffers severely because of unsatisfactory root absorption.

(7) *Root Relations*.—As an outcome of these findings, certain preliminary field data regarding root distribution of cacao growing in different soil-types in Trinidad that had been compiled in the past by various investigators were brought

together and discussed by the writer in another article in *Tropical Agriculture* (*See References*), wherein an attempt was made to correlate root distribution with soil features, for example, structural porosity which is mainly decided, in a wide range of Trinidadian soil-types, by organic matter content. These studies are being continued.

(8) In view of the fact that researches into soil aeration and the ecological relationships of cacao roots were not specifically performed under the aegis of the Cacao Research Scheme, they will not be further considered in this Eleventh Report which will be devoted solely to the publication of Dr. Humphries' physiological reports.

Plant Physiological Research

(9) Dr. Humphries' first paper indicates significantly—different physiological behaviour with regards to cherelle wilting between three different clones of I.C.S. cacao growing at two contrasted sites where the soil differs in nutrient status. His second paper traces the changes in the carbohydrate and fat components of the cacao pod during its development, as well as of the water and the dry matter contents, and his third mentions certain concomitant changes in mineral components.

(10) In his series of papers on the dormancy of cacao buds, the first announces a new and important discovery, namely that a close relationship apparently exists in Trinidad between leaf-flushing and air temperature. Above an air temperature of 83°F, conditions seem to be suitable for bud activity, and leaf flushing occurs. This temperature effect may have far-reaching consequences, especially in connection with the efficacy of shade in cacao plantations; it is being further studied. The second paper with Mr. R. K. McKee of the Botanical Section, concerns the carbohydrate changes during flushing which may exert considerable effect on cropping. The last paper describes the fluctuations in trunk circumference of a cacao tree which are shown to be connected both with cambial activity involved in leaf flushing, and with the effects of rain which causes variations in the degree of hydration of the tree tissues by water absorbed from the soil.

References

(List of articles on Cacao Research, Chemical Division, published or submitted for publication during the three years' period).

(A) CACAO PHYSIOLOGY

1. Wilt of Cacao Fruits (*Theobroma cacao*) I: An Investigation into the Causes. By E. C. Humphries, *Ann. Bot.*, 1943, N. S. VII, pp. 31-44.
2. Wilt of Cacao Fruits (*Theobroma cacao*) II: A Preliminary Survey of the Carbohydrate Metabolism with Special Reference to Wilt Susceptibility. By E. C. Humphries, *Ann. Bot.*, 1943, N. S. VII, pp. 45-61.
3. Wilt of Cacao Fruits (*Theobroma cacao*) III: Changes in Mineral Content during Development. By E. C. Humphries, *Ann. Bot.*, 1944, N. S. VIII, pp. 56-70.
4. A Consideration of Factors Controlling Bud Bursting in the Cacao Tree (*Theobroma cacao*). By E. C. Humphries, *Ann. Bot.*, (in the press).

(B) CACAO BIOCHEMISTRY

5. Cacao Tannin. Letter to *Nature*, by E. C. Humphries, 1943, 152, p. 509.
6. Studies on Tannin Compounds I: Changes during Autolysis of Minced Cacao Bean. By E. C. Humphries, *Biochem. J.* (in the press).

(C) CACAO ECOLOGY

7. Studies on Aeration of Cacao Soils in Trinidad, Pts. I, II, III, IV: by H. Vine, H. A. Thompson and F. Hardy. *Trop. Agric.*, 1942, XIX, pp. 175; 215; 1943, XX, pp. 13; 51.
8. Studies on Aeration and Water Supply in some Cacao Soils of Trinidad: by F. Hardy, *Trop. Agric.*, 1943, XX, p. 89.
9. The Root System of Cacao, by C. W. R. McCreary, J. A. McDonald, V. I. Mulloon and F. Hardy, *Trop. Agric.*, 1943, XX, p. 207.

(A) STUDIES IN THE PHYSIOLOGY OF THEOBROMA CACAO WITH SPECIAL REFERENCE TO CHERELLE WILT

FURTHER PROGRESS REPORT

By E. C. HUMPHRIES

(1) A Comparison of the Wilting Behaviour of Certain I.C.S. Selections on Two Different Sites

The object of this experiment was to compare the behaviour of the three clones, I.C.S. 1, 4 and 45, in regard to fruit wilt. These trees were situated on two distinct soil-types having different production potentialities. The first site was located in El Dorado Field of San Juan Estate, situated in the Montserrat District of Trinidad. The trees selected for experiment were six years old and in their third year of bearing. The soil of the experimental plot is a friable, chocolate-brown clay-loam, fairly well supplied with organic matter and rich in available plant nutrients* (4). Trees of the same clones growing at River Estate were also kept under observation. These were five years old at the time of the experiment. The soil at this site is a fine loamy-sand and less

nutrient rich in contrast to that of the first site*. The non-capillary pore-space is high in the surface 6-ins. but relatively low in the second at the San Juan site, and fairly high in both layers 6-ins. layer at the River Estate site. Thus the River Estate site shows slightly better natural underdrainage.

The three clones selected are broadly representative of the different types of Trinidad cacao; I.C.S. 1 may be described as good Forastero; it bears a large red pod with large beans and a shell of medium thickness; I.C.S. 4 bears a rounded green pod with a somewhat thick wall and shows little evidence of any Criollo characters; I.C.S. 45 is obviously a Criollo type with long oval, somewhat warty pods, having large beans, most of which are unpigmented. Further details regarding these selections are given by Pound (5, 6).

* Comparison of the nutrient status of the soil of the two experimental plots:

	Depth (ins.)	Index of texture	pH value	Total org. matter (%)	Total nitrogen (%)	C/N ratio	Avail. P ₂ O ₅ (p.p.m.)	Avail. K ₂ O (p.p.m.)	Pore-space	
									Capil- lary (vol. %)	Non- capil- lary (vol. %)
San Juan Estate plot	0-6	45	6.6	6.0	0.36	9.5	104	224	34	32
	6-12	44	6.5	4.4	0.27	9.3	61	—	42	18
River Estate plot	0-6	26	5.8	3.1	0.18	9.8	13	89	30	24
	6-12	27	5.6	2.7	0.16	9.6	11	—	32	21

Note: The San Juan soil belongs to the Montserrat Clay-Silt ("Chocolate") soil-type, but is not quite typical of it.

The River Estate soil belongs to the River Fine Sand (Alluvial) soil-type.

EXPERIMENTAL RESULTS

Two trees of each clone on each estate were kept under observation and visited weekly. Each new cherelle was given a serial number and the condition of fruits previously marked was recorded. The data obtained have been analysed as in previous investigations (Humphries, 1, 3). In the case of I.C.S. 1 at both sites, there was a rapid decrease in the size attained by the cherelles when wilting took place following a slight initial rise, this size reaching a very low value at the end of September. At this time practically all the fruits remaining on the trees had wilted, and the trees on both estates were exhibiting a heavy leaf flush. This is illustrated in Figure 1 where the downward-pointing arrows indicate the dates when the leaf-flush at each site was at its height. The actual figures are given in Table 1. The data indicate that extensive change of leaf caused complete loss of young fruits. The flush occurred at a time when the fruits set early in the season had not

passed the critical size beyond which they are capable of survival even under somewhat adverse conditions. Thus at River Estate none of the fruits set in the period before the flush survived, and at San Juan Estate only a few of those set at the beginning of this period matured. This is illustrated both in Figure 1 and Table 1 where the percentages of fruits becoming ripe or diseased of those set in successive weeks are shown. There are several possible explanations of the fact that some of the fruits set in this period on the San Juan trees ultimately ripened, whereas those set on the River Estate trees did not. It may be that the San Juan trees (which are slightly older and a good deal larger than the River Estate trees) contained greater reserves of nutrient materials and were able to supply both the flush and some of the developing fruits, whereas the demands of the growing leaves was so considerable in the River Estate trees that the supply to the fruits was curtailed with consequent wilting. There is

Table 1

COMPARISON OF THE FRUITS SET AND THEIR SUBSEQUENT FATE ON TREES OF I.C.S.1 AT RIVER ESTATE AND SAN JUAN ESTATE

RIVER ESTATE					SAN JUAN ESTATE				
Date of setting : 1941-42 week ending	No. of fruit set	Size at wilting (cm.)	% ripe or diseased of total set		Date of setting : 1941-42 week ending	No. of fruit set	Size at wilting (cm.)	% ripe or diseased of total set	
July 25	...	4	4.7	0	July 17	...	15	5.2	13
Aug. 1	...	11	5.0	0	" 24	...	11	5.7	18
" 8	...	12	6.0	0	" 31	...	3	5.9	33
" 15	...	6	4.4	0	Aug. 7	...	4	5.9	0
" 22	...	3	7.4	0	" 14	...	0	—	0
" 29	...	4	3.5	0	" 21	...	6	4.3	0
Sept. 5	...	10	2.3	0	" 28	...	5	4.3	0
" 12	...	28	1.6	0	Sept. 4	...	17	3.5	0
" 19	...	12	1.1	0	" 11	...	26	2.8	0
" 26	...	4	0.4	0	" 18	...	40	2.2	5
Oct. 3	...	0	—	0	" 25	...	27	1.7	0
" 10	...	1	—	0	Oct. 2	...	19	1.3	5
" 14	...	1	—	100	" 9	...	7	1.5	57
" 21	...	1	—	0	" 16	...	14	3.2	36
" 28	...	9	5.0	11	" 23	...	9	3.0	22
Nov. 4	...	8	3.7	0	" 30	...	17	1.0	41
" 11	...	16	2.7	13	Nov. 6	...	4	—	25
" 18	...	21	6.0	25	" 13	...	44	2.9	5
" 25	...	10	4.8	30	" 20	...	39	9.1	5
Dec. 2	...	19	6.3	6	" 27	...	25	5.1	12
" 9	...	6	3.3	0	Dec. 4	...	19	3.7	15
" 16	...	8	4.3	0	" 11	...	8	7.5	25
" 23	...	9	5.2	22	" 18	...	11	4.8	9
Jan. 2	...	20	4.3	0	" 24	...	12	6.1	8
" 9	...	11	3.8	0	" 31	...	12	4.4	0
" 16	...	9	2.6	0	Jan. 8	...	58	4.5	12
" 23	...	4	3.5	0	" 15	...	40	4.0	8
" 30	...	3	2.2	33	" 22	...	13	4.3	0
Feb. 6	...	1	3.1	0	" 29	...	18	3.3	11
" 13	...	0	—	0	Feb. 5	...	10	2.6	0
Total	...	251		6	Total	...	533		10

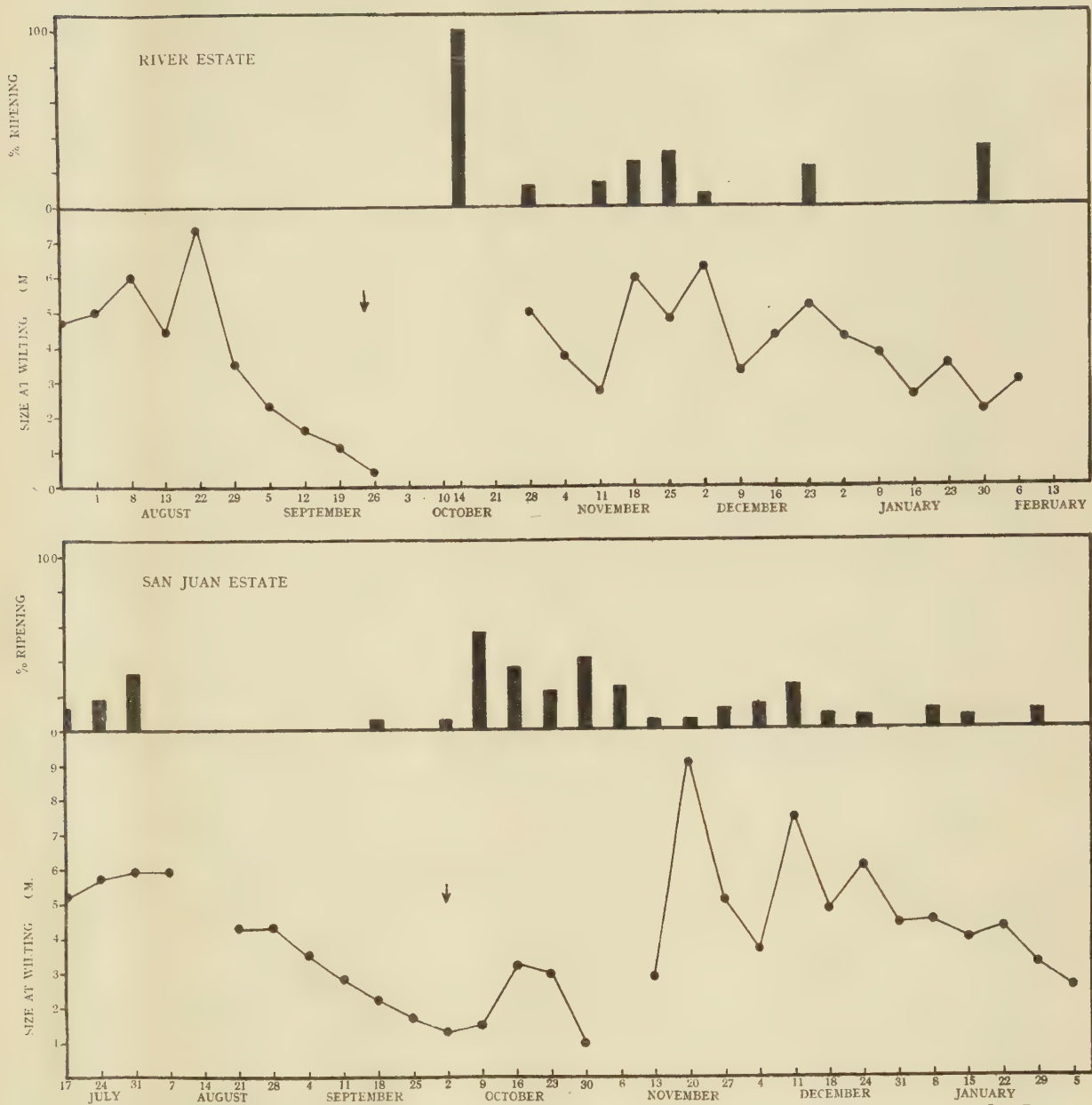


Fig. 1. The size at wilting of fruits set in successive weeks throughout the season on young trees of the clone I.C.S.1 at River Estate and San Juan Estate. The percentages of fruits becoming ripe from the weekly settings are also shown.

Table 2

COMPARISON OF THE FRUITS SET AND THEIR SUBSEQUENT FATE ON TREES OF L.C.S. 4 AND L.C.S. 45 AT RIVER ESTATE AND SAN JUAN ESTATE

[illegible]

evidence that the growth-rate of fruits on the trees at San Juan Estate is greater than at River Estate, so that it is possible that fruits at the former site reach their critical size more quickly than do fruits at the latter site, and this provides an alternative explanation. In any case there is no doubt that the soil fertility is much greater at San Juan Estate than at River Estate.

Some of the fruits which set immediately after the flush, however, became ripe. This was especially marked in the case of the San Juan trees. The size at wilting also increased and then diminished again as the crop on the tree matured. There were marked fluctuations in the size at wilting in this second period in contrast to the rather regular trend for mature trees. This, together with the fact that the young trees were so markedly affected by a leaf-flush, illustrates clearly that they are more susceptible to sudden changes in the distribution of nutrient materials, probably because they have smaller reserves to draw upon than mature trees. Consequently they are also much more affected by adverse changes in environment than old established trees.

The fact that a large proportion of the fruits set immediately after the leaf-flush reached maturity, also suggests that the general nutritional status of the tree is improved by the large number of young leaves then present which probably have a greater photosynthetic efficiency.

Setting was comparatively poor on trees of the other two clones, I.C.S. 4 and I.C.S. 45, at both estates, and it is difficult to draw conclusions from the sparse data available. Setting was also discontinuous, so that no definite trends are obvious and the small number of fruits set make averages unreliable. The data obtained from these two clones on the two estates are given in Table 2 for the sake of comparison. An interesting point is that, under the prevailing conditions, I.C.S. 1 set fruit more freely than the other two clones. Another fact which the figures illustrate is that there appears to be some similarity as regards fruit setting in the same clones on the two estates which may be related to the rainfall distribution (See Table 3). For instance, during October and November, only thirteen fruits set at River Estate and nineteen fruits at San Juan Estate on the clone I.C.S. 4, while twenty-one and one are the corresponding figures for I.C.S. 45. From Table 1 it will be noticed that, although I.C.S. 1 did not set many fruits at River Estate during October (which was a rather dry month), there was no very marked fall in setting on this clone during this month at San Juan Estate where the rainfall was higher. In November a large number of fruits was set at both estates. At San Juan almost the highest number of fruits was set at this time than at any similar period during the whole season. The behaviour of I.C.S. 1 thus stands out in marked contrast to that of the other two clones during October and November.

Table 3

COMPARISON OF THE MONTHLY RAINFALLS AT RIVER ESTATE AND SAN JUAN ESTATE

	River Estate	San Juan Estate*
1941	(inches)	(inches)
June ...	5.58	11.45
July ...	8.82	12.55
August ...	10.14	20.71
September ...	13.14	4.47
October ...	6.65	17.11
November ...	5.77	14.16
December ...	5.64	6.40
1942		
January ...	0.89	2.47
February ...	0.67	0.72
March ...	0.00	0.99

* No consecutive figures were available for the rainfall at San Juan Estate and those given are for La Vega Estate about 2 miles away.

On both estates, the I.C.S. 45 variety was remarkable for its lateness in setting. Some of the fruits that were set each week from the beginning of December became mature and consequently bore most of the crop in the dry season with a consequent diminution in yield per fruit.

It is of interest to note that the percentage number of fruits becoming ripe or diseased of the total set on each clone is in all cases greater at San Juan Estate than at River Estate, a fact which may again be correlated with the greater soil fertility at the former site.

(2) The Changes in Water-content, Dry Matter, Carbohydrates and Fat during the Development of the Pod

Field observations have shown, (Humphries, 1), that young cacao fruits are susceptible to wilt up to an age of about 70 days; subsequently, they either reach maturity or become diseased. In an attempt to explain these results in relation to the metabolism of different parts of the fruit during development, a series of investigations was planned to trace the broad changes which take place during the growth of the pod. The first of these investigations, which was concerned with the carbohydrate changes, has now been completed. A summary will here be presented.

Samples of pods of one variety of cacao of various ages from the time of fertilisation to maturity were collected in the manner already described, (Humphries, 2). Each of the samples was subdivided into (a) fruit wall and (b) the tissues included within the wall which have been called "pulp". The samples were boiled in alcohol and preserved for subsequent analyses of sucrose, glucose, fructose, glycosidic-glucose, starch, alcohol-soluble material and fat.

Each of the two parts of the fruit showed a rapid increase in weight as development proceeded, the wall maintaining its superior weight throughout

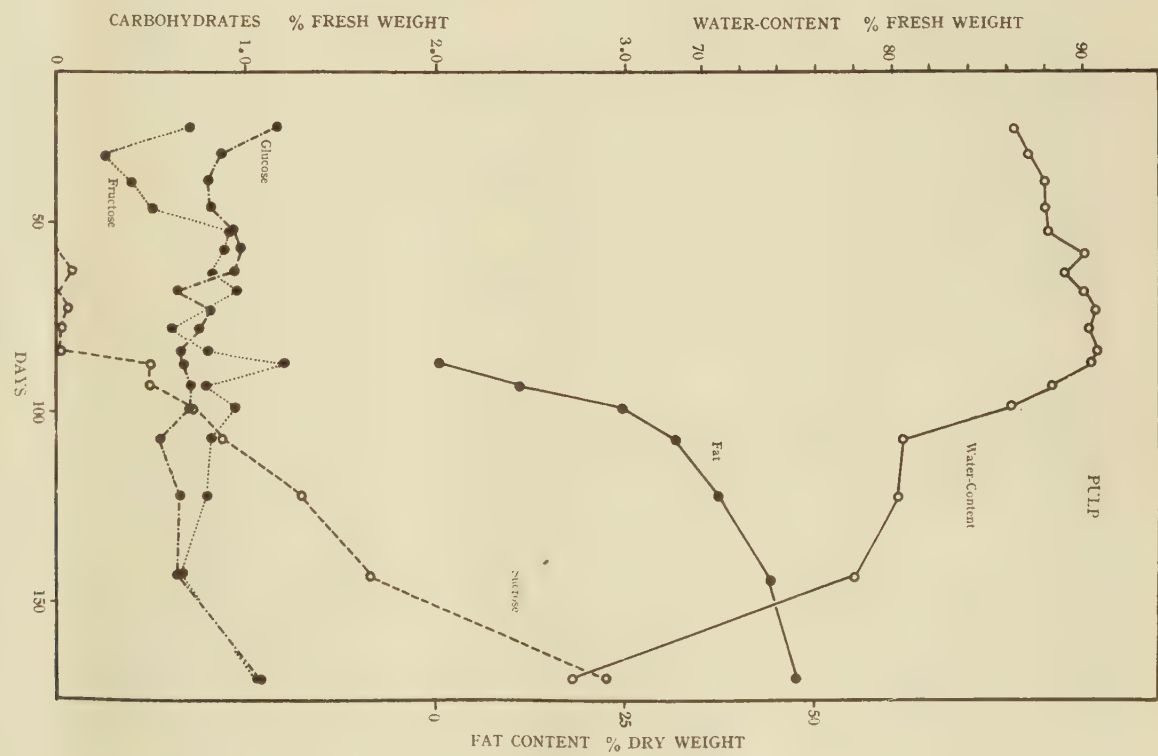
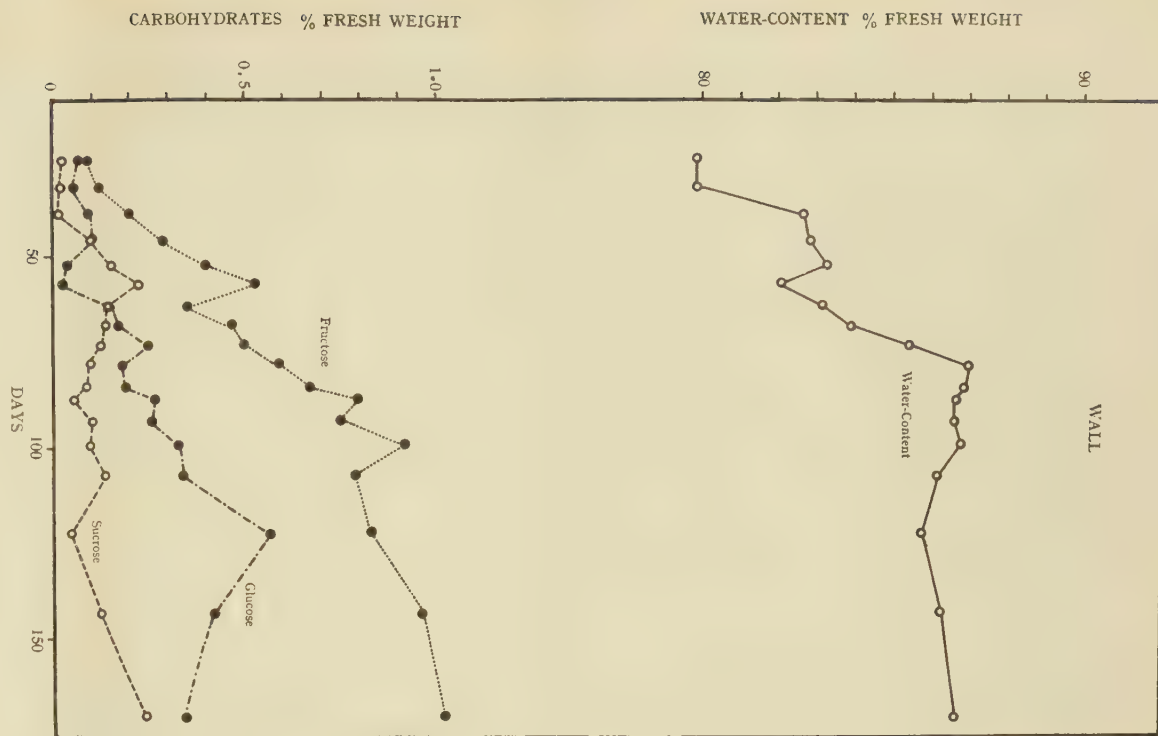


Fig. 2. The changes in water content, fructose, glucose, sucrose and fat in the wall and pulp of a cacao pod during development.

development. The wall/pulp ratio in respect of both fresh and dry weight declined throughout until the period of ripening, when the ratio of fresh weights increased slightly. The pulp decreased in fresh weight on ripening, but showed a big increase in dry weight and hence a big decrease in water content. The wall showed a very slight increase in water content. The absolute amount of water per fruit for different stages of development indicated that, during the ripening period, there was no net increase in the amount of water present in the fruit, but that there was a transfer of water from the pulp to the wall.

The data obtained in this investigation indicate that the growth period of the cacao fruit, which is approximately 170 days, falls naturally into 2 phases:—

- (1) a developmental phase occupying about 75 days,
- (2) a maturation phase in which metabolic activity is increased.

(1) *Developmental Phase*: During this time, the water contents (expressed as percentages of fresh weight) of the wall and the pulp increase from the time of fertilisation and reach their maxima at the end of this phase (See Figure 2). Field observations of growing fruit had previously shown that the fruit is liable to physiological wilt at any time during the first 75 days.

The development phase may be divided into two distinct periods; the *first period* covers an interval of about 50 days, at the end of which the first division of the zygote occurs. Fertilisation is followed by exponential increase in dry matter of both wall and pulp, the exponential constant up to 50 days being the same in both parts. The percentage amount of fructose in the wall increase throughout this period, while glucose increases slightly and falls to a minimum at the time of division of the zygote. Sucrose in the wall reaches a maximum at 50 days. In the pulp, the percentages of both fructose and glucose fall and then rise again to approximate equality at the end of the period. The *second period* (50-75 days), commences with the division of the zygote and the metabolic changes are undoubtedly associated with the preliminary development of the embryo. This second period is not well defined as far as carbohydrate changes in the wall are concerned; the percentage water content, however, is still increasing. The exponential constant for increase in dry weight falls to a lower value during this period, but the rate in the pulp remains at the original level. The concentrations of fructose and glucose are practically equal in the pulp and both decrease during the period. Very little sucrose is present.

(2) *The Phase of Active Metabolism and Maturation*: In this second phase metabolic activity is markedly increased. The phase falls into three periods. The *first period* (75-87 days) is characterised by the commencement of sucrose formation, while fructose (percentage amount) rises to a maximum at the end of the period. The percentage

of glucose continues to diminish. Formation of fat takes place rapidly in the pulp during the *second period* (87-143 days). The saponification value of the fat (which is high at first) rapidly decreases. The percentage of fructose falls throughout the second period while the glucose remains practically constant. Sucrose and starch continue to accumulate rapidly. The values for glycosidic-glucose increase greatly soon after the beginning of this period at the same time that the cotyledons become coloured purple by anthocyanin development. Fat is present both in the testa and in the cotyledons of the seed at this stage.

At the beginning of the *third period* (143-170 days) the fruit has reached its full size and ripening commences. In the wall, fructose continues to increase and glucose to decrease. Sucrose increases slightly. In the pulp, sucrose, starch and fat continue to increase and the concentrations of glucose and fructose again become equal. No fat is present in the testa at maturity. Glycosidic-glucose (anthocyanin) continues to increase. At about 170 days, the fruit is ripe as indicated externally by colour changes and internally by the separation of the seeds from the wall each surrounded by white tissue.

(3) Changes in the Mineral Content of the Wall and Pulp during Development

Ash analyses of the subdivisions of the cacao fruit (wall and pulp) were carried out at different stages of development with the object of establishing the approximate requirements of certain inorganic elements at different ages. There are indications that the uptake of minerals follows the dry weight increases fairly closely in the early stages, and that the exponential constants for uptake of potassium, phosphorus, calcium and magnesium are the same in both wall and pulp up to the age of 50 days; subsequently the rate diminishes in the wall but falls to a new constant value.

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(B) DORMANCY OF CACAO BUDS**(I) A CONSIDERATION OF THE FACTORS CONCERNED IN THE BREAKING OF THE REST PERIOD**

BY E. C. HUMPHRIES

Introduction

Periodic renewal of bud-activity is a characteristic phenomenon in many tropical trees resulting in the rapid production of a new set of leaves. This commonly occurs in the cacao tree in Trinidad and elsewhere, and a new "flush" of leaves is said to be produced.

A knowledge of the factors causing flushing in the cacao tree is desirable from the point of view of the entomologist, mycologist and plant physiologist. Certain insects, especially cacao thrips, exhibit a preference for the young leaves, while the young buds are often the seat of infection for witches'-broom disease. It is also known that flushing may divert nutrient materials from the developing fruits, and in young trees especially it may thus cause considerable fruit wilt.

Hitherto investigations on the periodicity of flushing have failed to find any consistent connection between the time of flushing and meteorological or other conditions. MacDonald (4, 5) suggested that flushes coincide with the onset of drier conditions following a wet spell or coincide with a wet spell following dry weather (rise in soil moisture), but it is obvious that this explanation does not meet all cases. Pound (7) was able to associate only one flush out of four with weather changes; he showed (8), that applications of ammonium sulphate, sulphate of potash and superphosphate alone or in combination had no effect on the intensity or periodicity of flush.

Experimental

As already briefly mentioned (Humphries, 3), an experiment has been in progress since April, 1940, with the object of recording the frequency of occurrence of bud-bursting in cacao trees. The method adopted was to mark a number of dormant buds on each of the experimental trees and to record their vegetative condition at 14-day intervals. These observations have been carried on for a period of two years.

Originally twelve trees were selected for tagging, nine trees in various parts of the College Botany plots and three trees at River Estate, viz. Nos. 33, 392, 894, constituting clonal budded and grafted material already the subject of various experiments (Humphries, 2, 3). In addition, a larger number of trees were kept under observation at River Estate and La Reconnaissance Estate,* Lopinot, and the flushing frequency noted by a different method to be described later. The trees at the College were kept under observation only until June, 1941, and then most of the trees became unhealthy and were no longer suitable for observation.

* For the results from this estate I am indebted to Professor Hardy.

During the first year of the experiment, twenty buds were kept under observation on each tree but subsequently the number was increased to thirty to afford a more representative sample. There was slight loss of buds from time to time, especially towards the end of the dry season. The data obtained from the three River Estate trees have been plotted (Figure 1) in the following manner:—the number of buds bursting at any given time has been expressed as a percentage of the total number of healthy buds still present on the tree. The value of the percentage is taken as a measure of the flushing intensity. This is shown by means of thick upright columns in Figure 1. It will be noticed that a big flush occurred on the three trees soon after the commencement of observations (May-June), and that subsequently there was a less intense flush in September-October. There was no further bud-activity on either of the trees until February of the next year when nearly all the marked buds burst at the same time. After an interval of about seven weeks, a lighter flush occurred which was followed after a similar interval by yet another flush. The next flush occurred in September-October with a very slight-flush on two of the trees in November. The following January there was another flush on all the trees, somewhat earlier than in the previous year. Subsequently two more flushes followed at about seven or eight week intervals as in the preceding dry season.

From this method of estimating flushing intensity, it is not possible to discover how soon after a bud has burst on an individual twig the new bud formed at the end of that particular growth is capable of sprouting again. The data have been further analysed, therefore, and the flushing frequency of buds on individual twigs on Tree 322 during the second year has been set out in Table 1. At the end of the first year when the number of buds under observation was increased to thirty, additional buds were also marked to replace those which had died during the year; hence records for more than thirty buds occur in this table. It may be noticed that some individual branches flushed at quite frequent intervals, for instance, Branch No. 6 burst on March 17th, and again on April 14th, an interval of only four weeks. Frequent flushing at fairly short intervals was by no means uncommon at the height of the dry season; thus Branch 32 flushed on February 3rd, again on March 31st (eight weeks), and again on May 12th (six weeks), and in the other two trees there was a similar tendency towards flushing at frequent intervals. For instance, in Branch 32 on Tree 33 the bud burst on November 4th and it subsequently flushed again at intervals of ten weeks, eight weeks and

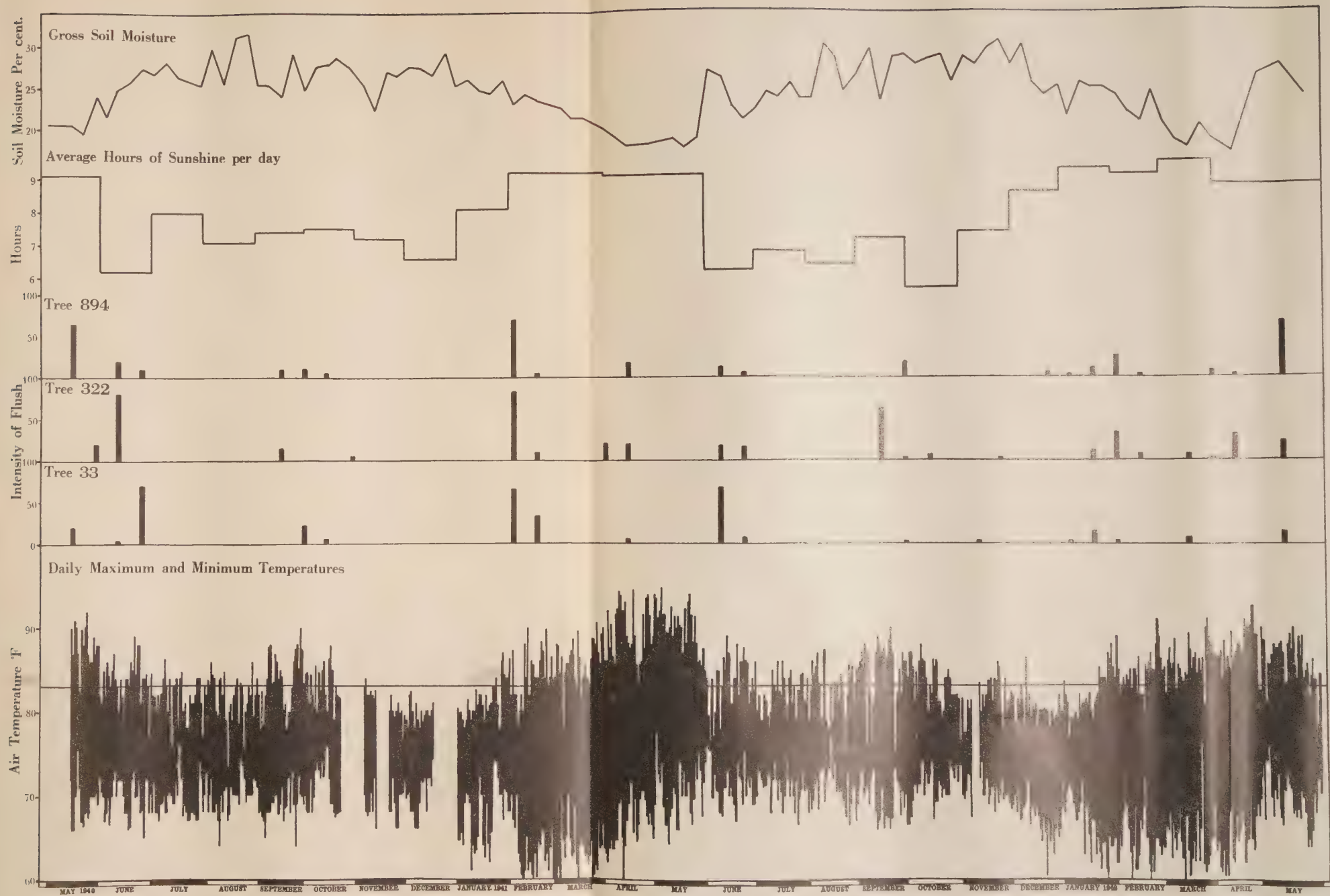


Fig. 1—The intensity of flush on Three Trees at River Estate over a two-year period and the daily maximum and minimum temperatures, the monthly averages of hours sunshine per day and the gross soil moisture content

THE PERIODICITY OF FLUSHING ON CERTAIN BRANCHES OF TREE 322

ten weeks. From these records it appears that the minimum resting period required by a cacao bud is approximately eight weeks. McKee (6), has shown that flushing takes place in young cacao trees under inadequate shade, regularly about every six or seven weeks.

In order to discover if periods of flush are in any way connected with environmental conditions, certain meteorological observations were recorded at the experimental sites. A thermo-hygrograph was maintained in a Stevenson screen adjacent to the trees under observation, and the temperatures recorded therein were checked at weekly intervals. Soil temperatures were also recorded at three inches depth. Soil samples were collected for moisture determination weekly, and rainfall figures were abstracted from the estate records. Since it is impossible to present all the meteorological data, a selection has been made in Figure 1 where the flushing frequencies are also shown. The daily maximum and minimum temperatures are abstracted from the continuous records of temperature in the Stevenson screen, and soil moisture contents from the weekly records. The monthly average hours of sunshine per day were abstracted from the College Meteorological records, being the only sunshine records available in Trinidad; in all probability quite representative of the average conditions at River Estate. There is no obvious relationship between the duration of sunlight and the frequency of flushing, since this often occurs in the middle of the dry season (February and March) when the average duration of sunlight is as high as nine hours per day, or in September-October when it may be as low as six hours. The question arises as to whether the length of day has any connection with flushing frequency. In the first place, the variation on day length in Trinidad is not very great, the maximum being about $12\frac{2}{3}$ hours and the minimum about $11\frac{1}{2}$ hours. The duration of daylight is 12 hours or over between March and September and at a minimum in December. It can readily be seen that flushing occurs both during the short day (Jan.-Feb.) as well as during the long day (June).

There appears to be a close relationship, however, between *flushing frequency and maximum temperature*. At the time that observations were begun (May, 1940), the daily maximum temperatures were high, but they gradually fell until about the beginning of July when they remained fairly steady to the end of August. During this initial period of high temperature, most of the buds burst. In September and October, the maximum temperatures again rose and there was also a fresh outburst of flushing. In November-December, temperatures were again lower and no flushing occurred on the observational trees. In January with the onset of the dry season, the maximum temperatures began to rise again, reaching a peak in April and May and falling off again in June. During this long period of high temperature, there were three distinct periods of bud activity, and reference to Table I shows that some individual

branches flushed at quite frequent intervals, although it was more often the case that, if a certain bud did not burst at one period, it did so at the next. After the dry season, there was no further activity until September-October when a further spell of high temperatures (the "petit carême") occurred. There was then a flush on all three trees (very slight on one) in the middle of this period. Apart from two very slight flushes in November, affecting only a few branches on two of the trees, when there was slight rise in maximum temperatures, the next flush occurred in January 1942, earlier than in the previous year. It is interesting to note that the dry season of that year commenced about the middle of the previous December which is abnormally early.

It is apparent from the data that flushing is very closely connected with periods of high maximum temperature. When the maximum temperature is above about 83° or 84°F (in the screen), conditions appear to be favourable for renewed bud activity. Minimum temperatures do not appear to show such a close relationship with flushing periodicity.

It might be argued that, since these observations concern only three trees, generalisation is not justified. Fortunately, however, other observations are available. A number of trees at La Reconnaissance Estate, Lopinot, the site of a soil experiment by Professor Hardy, were kept under observation for two years. In all there were three plots of mature estate trees (not clonal) with fifteen in one plot and eight in each of the others. The method adopted here in assessing the flushing intensity was somewhat different in order to enable the larger number of trees to be kept under observation. The trees were individually inspected every week and given marks ranging from $\frac{1}{2}$ to 6 according to the intensity of flush. The scale of marks ranged as follows:—

- 0—no flush
 - $\frac{1}{2}$ —less than ten flushes on the whole tree
 - 1—some, but comparatively few flushes
 - 2—flushes over about one third of the tree
 - 3—flushes over about one half of the tree
 - 4—flushes over about two-thirds of the tree
 - 5—flushes over nearly the whole tree
 - 6—flushes over the whole tree
- (cf. Pyke (9))

In order to assess the average behaviour of the trees in each plot from week to week, the mean of the marks has been taken. This constitutes therefore a general method in contrast to the intensive method already described, and the two methods provide a convenient check against one another. The results obtained over a two year period for the plot of 15 trees are presented in Figure 2 where the average weekly maximum air temperatures are also shown. The results for the other two plots are essentially the same and are not here presented. Again there is a striking connection between the maximum air temperatures and the degree of flush on the tree. When the maximum temperatures are high (and especially at the commencement of period of high

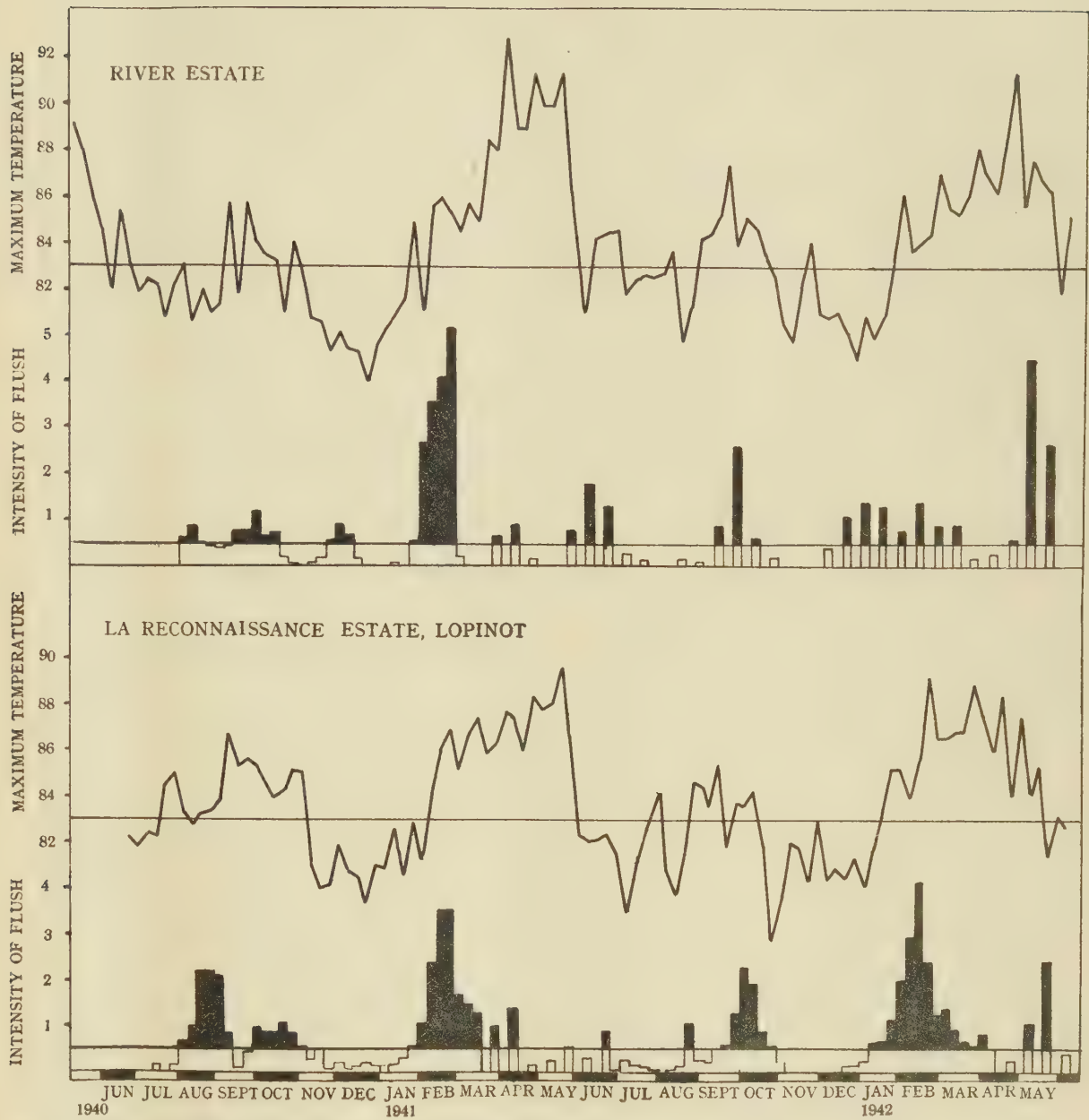


Fig. 2. The relationship between the average flushing intensity of trees at River Estate and La Reconnaissance Estate, Lopinot and the weekly average maximum temperatures.

temperature), there is a considerable amount of bud activity. When temperatures are minimum, however, there is practically no flushing. It should be noted that, since the lowest marks given for flushing intensity was $\frac{1}{2}$, a line has been drawn at this level in Figure 2; indications of flush below this level may thus be neglected.

A plot of fourteen trees at River Estate was also kept under observation and flushing assessed by the general method. This plot consisted of clonal material of which the trees mentioned above as having been assessed by the intensive method form a part. Essentially the same result was obtained for this plot (Figure 2), except that the mark system gave indications of a slight flush at the periods of lowest maximums (November-December) in both years. Inspection of the detailed assessments of the individual trees shows that the fairly high marks for these two periods were largely due to the behaviour of three particular trees. It is possible that defoliation due to, thrips attack caused flushing during these periods but unfortunately no records of insect incidence were kept. No flushes at these particular times were recorded on the trees under intensive observation.

The evidence presented above therefore definitely indicates that *maximum temperature is closely correlated with bud bursting in cacao*. When the maximum air temperature (as indicated by thermometers in a Stevenson screen under the trees) is above a certain level (which in the cases recorded appears to be about 83°F), conditions are apparently suitable for renewed bud activity. When the maximum temperature is below this, normal flushing rarely, if ever, occurs. All the temperatures recorded were those of the air in the screen, there is no evidence of the temperature of the air at the leaf or bud surface itself which will presumably be somewhat higher, in the buds if not in the leaves, especially in the dry season when the shade trees (*Immortelles*) are bare, although this would lead to increased exposure of the screen also. In a well-shaded plot, however, it is reasonable to suppose that the leaves have *approximately* the temperature of the air. Shade is very beneficial in excluding direct sunlight.

It is possible that high temperature, *per se*, is not the factor responsible for inducing bud activity, since high temperature is merely one manifestation of other factors such as light intensity or internal pressure deficit, one or other of which may be the real causal agent of flushing. It seems clear, however, that measures which will tend to reduce air temperature or check its rise will be instrumental in reducing flushing intensity.

Discussion

Owing to its great importance, especially in fruit trees, a good deal of attention has been paid to the subject of bud dormancy. It has been found that a great number of diverse agents may cause dormant buds to renew their activity. These include warmth, cold, X-rays, various acids, certain oils, ether, alcohol, chloroform,

ethylene, thiourea, sodium thiocyanate, sodium nitrate, injected water, diastase and other chemical substances, while wounding or mere mechanical stimulation by rubbing the stem have been sufficient in some instances. Whether these agents act on a particular metabolic system or on different systems or at different stages in the system producing the same ultimate effect (namely, development of dormant buds) it is not possible to decide on the evidence available. Some of the earliest work on dormancy (Molisch and others) showed that the immersion of dormant twigs in warm water for a short period (9-12 hours) may cause dormant buds to burst and grow, provided subsequent conditions were favourable for growth. Molisch found that a temperature of 30°C (86°F) was the optimum temperature for a number of species but 35°-40°C was necessary for others. Furthermore he found that the response was confined to buds actually submerged in the bath; i.e. the effect was very localised. It was further shown that the effect could remain latent until a time when conditions again became favourable for growth. It is possible that bud activity in cacao is governed by a similar process. Many analytical studies have been made of the chemical changes taking place during dormancy and subsequent bud bursting, but they have not fully explained the mechanism by which various treatments bring about termination of the rest period. They are all responsible apparently for bringing about a certain internal condition necessary for the initiation of growth. In some cases, extensive changes, especially in carbohydrates, take place during the dormant period. Thus Gardiner (1), studying the changes taking place in pear shoots during the winter period found a large increase of hexose and sucrose, whereas for similar plants kept in a greenhouse where the temperature was never very low, he found much less marked changes. Similar effects have been observed in potatoes stored at different temperatures. It appears that both low temperatures and high temperatures are capable of inducing renewed growth, and in some cases they appear to be an essential preliminary to growth. The effect of different temperatures on bud activity in cacao may be determined by direct experiment and will be the subject of further study.

Much less is known about the growth responses of tropical trees as contrasted with temperate trees, and it may well be that periods of high temperature are as essential for renewal of bud activity in some tropical trees as periods of low temperature are for certain temperate trees. The Mango (*Mangifera indica*) appears to behave very similarly to cacao in its flushing habits although the new growth is often confined to certain branches. In temperate trees, the minimum dormant period necessary before renewal of activity appears to be quite long, but in cacao it appears that the dormant period need only be very short, in fact just about as long as is necessary for the new terminal bud to

reach maturity and at the same time to mobilise sufficient food reserves, a period of about seven weeks or less. This is probably because metabolic changes are much more rapid at tropical temperatures, and because there is never any period of the year which is unfavourable to growth. Even in the dry season when soil moisture is at a minimum, vigorous flushing may take place.

The view here put forward, that flushing in cacao is an effect of high temperature, is supported by certain general observations. Cacao trees on the outside of a plantation tend to flush more frequently than those inside, possibly because of more direct insolation. Flushing also occurs more frequently in "pockets" caused by the falling of cacao and Immortelle shade trees, and it is more marked under inadequate shade in the dry season. The theory also suggests why it is possible to have flushing both in the dry and wet season where conditions of rainfall, soil moisture and atmospheric humidity are directly opposed. This was previously the chief obstacle to any rational explanation of flushing frequency.

Whether frequent flushing is desirable is a matter which can scarcely be argued with limited present knowledge. More definite information is needed regarding the period of time over which a cacao leaf remains efficient, but it is safe to conclude that this period is certainly longer than seven or eight weeks. It is quite likely that extremely frequent flushing may effectively be reduced by the provision of more adequate shade.

Summary

A relationship between periodicity of flush in the cacao tree and maximum temperature of the atmosphere has been established.

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(B) DORMANCY OF CACAO BUDS—Continued
(II) : CARBOHYDRATE CHANGES DURING THE DEVELOPMENT OF A FLUSH

BY

E. C. HUMPHRIES AND R. K. MCKEE

THIS investigation was carried out at the same time that the previous one was proceeding, in an attempt to obtain as much information as possible about the changes taking place during the development of a flush and the conditions which initiate flushing. At the time of the experiment, a relationship between air temperature and flushing had not been suspected. The experiment was also designed to yield information about the carbohydrate reserves of the cacao tree.

Experimental Procedure

The method of sampling was similar to that adopted for following the changes in mineral content during the development of a flush (Humphries, 1). The same fifty trees (Parent 1304, River Estate) were used. The only modification in procedure was to collect both the new (developing) flush and the next immediately older flush from each marked twig. These are subsequently referred to as "young" and "old" flush respectively. The first sample was collected on October 3rd, 1941, and collections continued until January 2nd, 1942, giving fourteen samples, each consisting of at least forty flushes. The new flush and the next immediately older flush were separated and each was divided into leaves and stems (including petioles) so that four subsamples were collected each week. Each subsample was weighed and plunged into boiling alcohol and stored for subsequent analysis. The following determinations were made on each subsample: alcohol soluble material, total reducing sugars, sucrose and starch. The original dry weights of the tissues were obtained from the sum of the alcohol-soluble material and the alcohol-insoluble material.

Changes in Fresh Weight, Dry Weight and Water Content

The young flush increased rapidly in fresh weight and dry weight during the first five weeks, after which extension-growth of the stem and leaves ceased. This is illustrated in Figures 1c and 1d, where the average fresh weight and dry weight increases of the young leaves and young stems of a single flush are separately shown (see also Tables, 1, 2, 3, 4). From the sixth week onwards, the young leaves did not increase markedly in fresh-weight, and there was a slight decrease towards the end of the period though this was possibly due to actual loss of leaves from individual flushes. No record was kept of the actual number of leaves collected. In the case of the young and old stems, however, this error does not arise and sampling errors are the only ones which affect the accuracy of the dry weight and fresh weight curves for these samples.

Since a large sample was always collected, the sampling error is probably small, but no estimate of its magnitude is possible, because the samples were not duplicated. The fresh weight curve for old stems (Figure 1c, Table 4) shows a slight increase over the first five weeks and then a more rapid increase to a maximum at eight weeks, after which there is a gradual decline until the 14th week, except for a high value at the 12th week. The fresh weight curve of the young stems (Figure 1c, Table 4), however, increases until the eighth week and then remains practically constant.

The changes in fresh weight and dry weight of the old leaves are shown in Figures 1c and 1d and Table 1. The curves are very similar in form, and both show a decrease during the first six weeks of sampling, which is partly accounted for by the transport of substances including minerals, out of the leaf (See Humphries, *loc. cit.*). Subsequently there is a steady rise until the 11th week and then a decline.

The changes in water content of the parts of the flush during development are shown in Figures 1a and 1b and Tables 1, 2, 3, 4. The young leaves showed a slight initial increase in water content and then a rapid decrease until the fifth week, after which the decrease was more gradual. The stem also showed a rapid decrease in water content which lasted until the seventh week and subsequently the rate of decrease was less. The old leaves showed only a very slight decrease in water content over the observational period, fluctuating between fifty-five per cent. and sixty per cent. of the fresh weight. There appears to have been a small net decline over the whole period. The water content of the old stems fell slowly throughout. As already mentioned, the original dry weight, of the leaves and stems were obtained by the sums of the alcohol-soluble and alcohol-insoluble materials, and it is satisfactory to note that the water contents recorded agree very closely with those of a previous investigation (Humphries, *loc. cit.*) for flushes on the same set of trees but at a different period of the year when the dry weights were obtained directly by oven-drying.

Carbohydrate Changes in the Flush during Development

Old Leaves : Total Reducing Sugars, Sucrose and Starch.

The amount of total reducing sugars, expressed as percentage of fresh weight, showed little variation during the 14 weeks of observation (Fig. 2b, Table 1); they had a mean value of about 0.2 per cent. of the fresh weight but rose somewhat in the 11th and 12th weeks and fell again to about the previous level. Sucrose, however, showed more marked fluctuations. The

Table 1

PROGRESSIVE CHANGES IN FRESH-WEIGHT, DRY-WEIGHT, WATER-CONTENT, TOTAL REDUCING SUGARS
SUCROSE AND STARCH IN THE LEAVES OF THE OLD FLUSH

Week No.	Fresh weight of leaves of flush (g.)	Dry weight of leaves of flush (g.)	Water content of leaves (Per cent. fresh weight)	Total reducing sugars (Per cent. fresh weight)	Sucrose (Per cent. fresh weight)	Starch (Per cent. dry weight)
1 ...	7.53	3.01	60.06	—	—	0.48
2 ...	7.52	—	—	0.17	0.53	—
3 ...	6.13	2.50	59.20	0.21	0.62	0.52
4 ...	4.83	2.15	55.49	0.21	0.42	0.52
5 ...	5.30	2.25	57.56	0.22	0.75	0.33
6 ...	4.50	1.80	60.12	0.22	0.51	0.51
7 ...	6.46	2.65	58.94	0.20	0.55	0.61
8 ...	6.70	2.75	58.89	0.19	0.73	0.66
9 ...	7.37	3.28	55.48	0.22	1.09	0.47
10 ...	6.67	2.83	57.55	0.21	0.68	0.54
11 ...	8.09	3.54	56.26	0.25	0.69	0.60
12 ...	6.65	2.94	55.75	0.32	0.77	0.63
13 ...	5.45	2.30	57.86	0.21	0.69	0.63
14 ...	6.01	2.55	57.52	0.18	0.96	0.48

Table 2

PROGRESSIVE CHANGES IN FRESH-WEIGHT, DRY-WEIGHT, WATER-CONTENT, TOTAL REDUCING SUGARS,
SUCROSE AND STARCH IN THE STEMS OF THE OLD FLUSH

Week No.	Fresh weight of stems of one flush (g.)	Dry weight of stems of one flush (g.)	Water content of stems (Per cent. fresh weight)	Total reducing sugars (Per cent. fresh weight)	Sucrose (Per cent. fresh weight)	Starch (Per cent. dry weight)
1 ...	1.71	0.45	73.57	0.11	0.36	2.03
2 ...	1.88	0.51	72.70	0.13	0.39	2.12
3 ...	1.90	0.52	72.68	0.10	0.44	1.16
4 ...	1.80	0.52	71.40	0.11	0.31	1.29
5 ...	1.90	0.49	74.43	0.14	0.49	1.20
6 ...	2.05	0.58	71.81	0.14	0.41	1.53
7 ...	2.23	0.61	72.77	0.20	0.45	1.20
8 ...	2.72	0.76	71.92	0.16	0.41	1.58
9 ...	2.65	0.81	69.54	0.14	0.48	1.53
10 ...	2.43	0.70	71.09	0.14	0.42	2.13
11 ...	2.23	0.65	70.98	0.23	0.51	1.85
12 ...	2.72	0.86	68.25	0.32	0.13	2.42
13 ...	1.94	0.62	68.32	0.12	0.55	2.28
14 ...	2.39	0.74	69.12	0.13	0.48	2.58

Table 3

PROGRESSIVE CHANGES IN FRESH-WEIGHT, DRY-WEIGHT, WATER-CONTENT, TOTAL REDUCING SUGARS
SUCROSE AND STARCH IN THE LEAVES OF THE YOUNG FLUSH

Week No.	Fresh weight of leaves of one flush (g.)	Dry weight of leaves of one flush (g.)	Water content of leaves (Per cent. fresh weight)	Total reducing sugars (Per cent. fresh weight)	Sucrose (Per cent. fresh weight)	Starch (Per cent. dry weight)
1 ...	0.51	0.10	80.33	0.43	0.70	0.82
2 ...	1.95	0.35	82.01	0.20	0.78	0.65
3 ...	8.14	1.73	78.71	0.22	0.58	0.70
4 ...	7.36	2.16	70.72	0.24	0.36	0.56
5 ...	10.40	3.48	66.57	0.25	0.68	0.77
6 ...	9.95	3.17	68.11	0.31	0.74	0.65
7 ...	9.92	3.60	63.69	0.29	0.79	1.00
8 ...	11.00	4.07	62.99	0.24	0.69	0.71
9 ...	11.25	4.16	63.05	0.24	0.83	0.95
10 ...	10.25	3.87	62.22	0.23	0.85	0.86
11 ...	8.47	3.29	61.15	0.16	0.49	0.63
12 ...	10.73	4.10	61.77	0.17	0.91	0.70
13 ...	8.91	3.55	60.13	0.35	0.67	0.43
14 ...	9.41	3.74	60.25	0.18	1.10	0.66

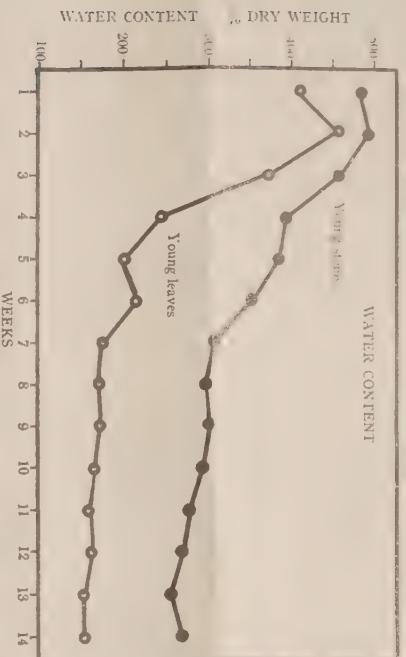


Fig. 1a The changes in water content of the stems and leaves of the young flush during a period of fourteen weeks

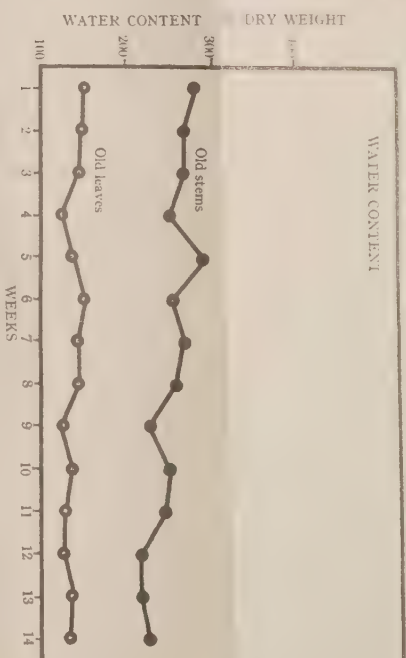


Fig. 1b The changes in water content of the stems and leaves of the old flush during a period of fourteen weeks

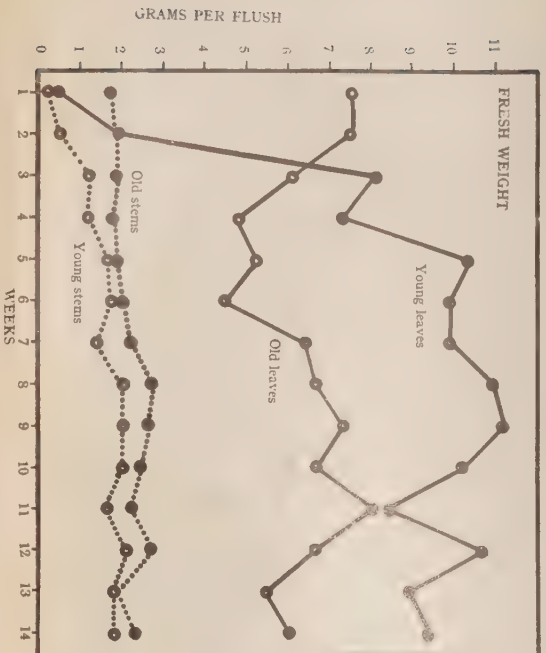


Fig. 1c The changes in fresh weight of the young stems, young leaves, old stems and old leaves of a single flush during a period of fourteen weeks

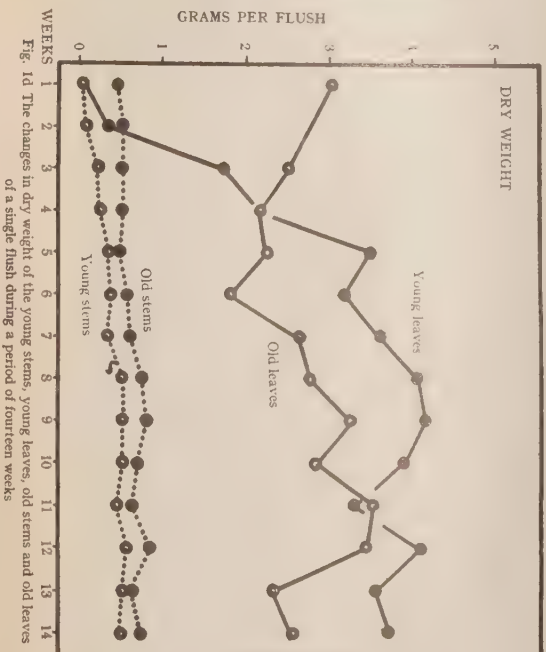


Fig. 1d The changes in dry weight of the young stems, young leaves, old stems and old leaves of a single flush during a period of fourteen weeks

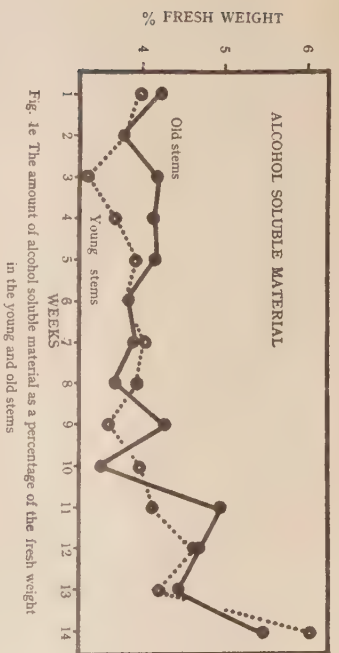


Fig. 1e The amount of alcohol soluble material as a percentage of the fresh weight in the young and old stems

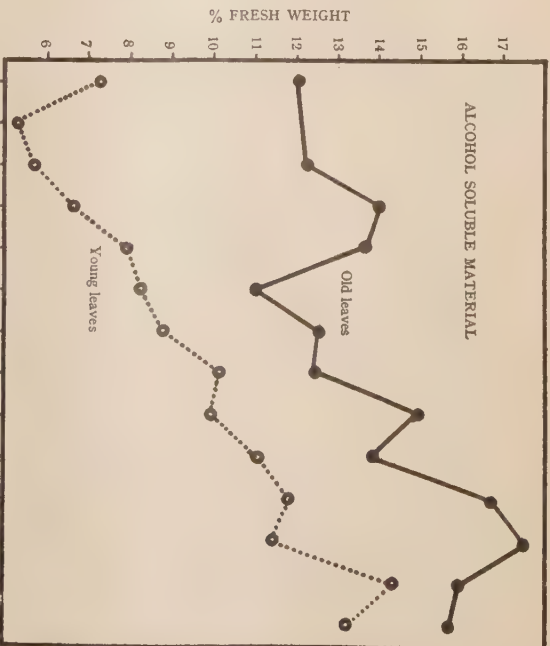


Fig. 1f The amount of alcohol soluble material as a percentage of the fresh weight in the young and old leaves

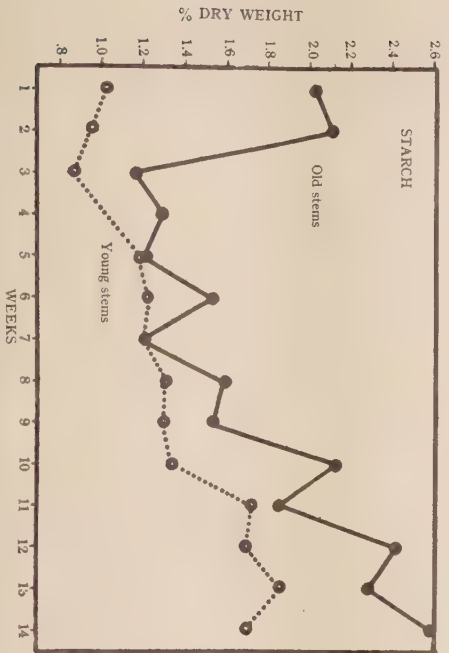


Fig. 1g The variation in starch content of the young and old stems during a period of fourteen weeks

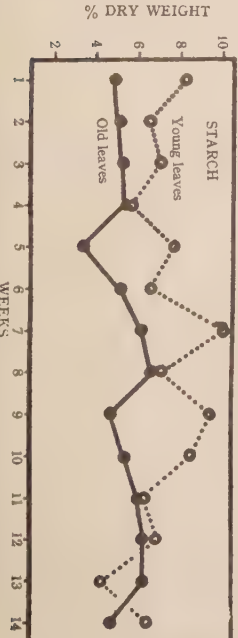


Fig. 1h The variation in starch content of the young and old leaves during a period of fourteen weeks

Table 4

PROGRESSIVE CHANGES IN FRESH-WEIGHT, DRY-WEIGHT, WATER-CONTENT, TOTAL REDUCING SUGARS, SUCROSE AND STARCH IN THE STEMS OF THE YOUNG FLUSH

Week No.	Fresh weight of stems of one flush (g.)	Dry weight of stems of one flush (g.)	Water content of stems (Per cent. fresh weight)	Total reducing sugars (Per cent. fresh weight)	Sucrose (Per cent. fresh weight)	Starch (Per cent. dry weight)
1 ...	0.25	0.04	82.91	0.16	0.46	1.03
2 ...	0.54	0.09	83.11	0.12	0.19	0.96
3 ...	1.28	0.23	82.06	0.13	0.14	0.87
4 ...	1.23	0.25	79.76	0.08	0.19	—
5 ...	1.70	0.35	79.38	0.11	0.29	1.18
6 ...	1.77	0.39	77.95	0.15	0.30	1.23
7 ...	1.44	0.35	75.40	0.09	0.43	1.20
8 ...	2.06	0.52	74.83	0.17	0.33	1.31
9 ...	2.05	0.51	74.95	0.19	0.42	1.30
10 ...	2.03	0.52	74.31	0.15	0.33	1.34
11 ...	1.67	0.45	73.21	0.16	0.50	1.72
12 ...	2.11	0.58	72.65	0.13	0.37	1.69
13 ...	1.82	0.52	71.70	0.14	0.43	1.86
14 ...	1.83	0.50	72.71	0.19	0.47	1.69

value ranged about 0.6 per cent. (Fig. 2b, Table 1) in the first five weeks and rose to a maximum value at 9 weeks and then fell somewhat to rise again in the last week. When expressed on the basis of sucrose per leaves of one old flush (Fig. 2f), the same general trend is observed with a maximum at the ninth week and a subsequent fall. The values for starch in the old leaves, expressed as per cent. of dry weight, are shown in Figure 1h and Table 1. On the whole, there is a very slight upward trend with low values at the 5th and 9th weeks when maxima occur in the sucrose curve.

Old Stems: Total Reducing Sugars, Sucrose and Starch

The total reducing sugars, as in the leaves, showed very little fluctuation during most of the period, but there was a very slight upward trend (Fig. 2d, Table 2). In the 12th week, the value was high but, at this time, the sucrose was exceedingly low and it is quite probable that there was inversion of sucrose during the storage of this sample. The sucrose value for the old stems (Fig. 2d, Table 2) showed little variation but a very slight upward trend is noticeable.

Starch values (Fig. 1g, Table 2) for old stems on a dry weight basis, showed a very marked decrease during the 2nd and 3rd weeks, which was undoubtedly due to hydrolysis and translocation to the developing flush. Starch soon began to accumulate at a steady rate in the old stems, and its amount passed the initial value after about the 12th week.

Young Leaves: Total Reducing Sugars, Sucrose and Starch

The values for total reducing sugars in the young leaves fluctuated more than in the old leaves. The value in the 2nd week (Fig. 2a, Table

3) was about 50 per cent. of the initial value and subsequently rose until the 6th week when the value fell again. The high value in the 13th week is apparently due to the inversion of sucrose during storage. The sucrose value (Fig. 2a, Table 3), fell to a low value in the 4th week and then rose, rapidly at first, then more slowly. Starch in the young leaves (Fig. 1h, Table 3) had a higher value than for old leaves, on a dry weight basis, during most of the period, but they became nearly equal at the end of 14 weeks, when the water content of the leaves was very similar. The starch values in the young leaves fluctuated more markedly than in the old leaves, and exhibited a maximum about the eighth week after which a steady decline was noticeable.

Young Stems: Total Reducing Sugars, Sucrose and Starch

The total reducing sugars in the young stems (Fig. 2c, Table 4), did not show very great variation. Sucrose (Fig. 2c, Table 4), on the other hand, showed a fairly well-marked trend; there was a sharp decline at first in the percentage amount, but subsequently there was a steady rise until, at 14 weeks, the initial value had again been attained. Starch in the young stems (Fig. 1g, Table 4), showed a slight decline on the per cent. dry weight during the first three weeks, but subsequently there was a steady rise which became somewhat more rapid towards the end of the period.

Alcohol Soluble Material

The total alcohol-soluble material in each of the samples was also determined and expressed as a percentage of the fresh weight. From a consideration of this data it is possible to obtain some idea of what changes take place in some other substances besides carbohydrates. In Table 5 are shown the amounts of alcohol-soluble

Table 5

ALCOHOL-SOLUBLE MATERIAL PER 100 g. FRESH WEIGHT IN THE STEMS AND LEAVES OF THE YOUNG AND OLD FLUSHES

Week No.	Young leaves	Young stems	Old leaves	Old stems
1	5.81	3.28	7.25	3.19
2	4.31	3.14	(5.20)	2.73
3	4.48	2.75	7.23	3.02
4	4.69	2.92	7.79	2.96
5	5.27	3.12	7.90	3.08
6	5.61	2.96	6.63	2.76
7	5.58	3.03	7.39	2.82
8	6.37	2.93	7.31	2.64
9	6.30	2.69	8.32	2.98
10	6.91	2.96	8.01	2.50
11	7.32	3.04	9.45	3.51
12	7.10	3.39	9.76	3.22
13	8.64	3.04	9.20	3.02
14	7.98	4.39	8.99	3.80

material in 100 g. of fresh material in the stems and leaves of the young and old flush during the 14-week period. In both young leaves and old leaves there was a steady rise in the percentage of alcohol-soluble materials, but in both there was a decline in water content. It is therefore important to study the trend of the alcohol-soluble material per 100 g. water. This is expressed in Figure 1f. It is apparent that, in the case of the young leaves, there was a continuous rise in the amount of alcohol-soluble materials associated with 100 g. water. The amount in the old leaves also rose, but not so rapidly. This may be an indication that active metabolism was taking place in the old leaves, and that substances were accumulating despite the almost constant water content. The alcohol-soluble material, expressed as per cent. of fresh weight (Table 5) of the young and old stems, remained practically constant, with perhaps a very slight downward trend, until the 10th week when there was an increase in both cases. These data, when expressed on a basis of 100 g. water, are shown in Figure 1e. The values for both young stems and old stems follow one another very closely and remain practically constant for the first 10 weeks, after which both show a sharp rise, the values for the 14th week being nearly 50 per cent. higher than those in the 10th week. Expressed

in absolute amounts, there was an increase of about 4 g. of alcohol soluble material per 100 g. water at 10 weeks, to nearly 6 g. at 14 weeks. Total sugars apparently did not account for any of this increase in alcohol-soluble material, as reference to the values for sugars, expressed as per cent. of fresh weight, and the corresponding water content figures show (See Tables 1-4). It is not possible to say what substance or substances were responsible for the rapid increase in value, but nitrogenous substances may have been concerned. In the 12th and 13th weeks, some of the marked flushes had begun to sprout again and were rejected for this reason. Hence the sudden increase in alcohol-soluble material may be indicative of changes taking place preparatory to a flush.

Discussion

The carbohydrate changes in the young flush during development and the concurrent changes in the next immediately older flush here described, show that the total reducing sugars remained fairly constant throughout the period of investigation. The sucrose content, on the other hand, fluctuated considerably, and there is evidence that these fluctuations were connected with the maximum air temperatures, though more detailed investigation is needed. The changes in starch content in both young and old stems afford some idea of how soon after a flush commences the starch reserves again reach their former level. In the old stems, starch reserves are depleted immediately the young flush commences development, and the original content is not regained until about the 11th or 12th week. It is thus extremely probable that, if flushing takes place very frequently (say every 8 weeks), the available reserves are capable of supporting only a limited amount of growth, and the successive flushes consequently will become progressively smaller and weaker. The significance of the marked increase in alcohol-soluble material in the stems towards the end of the period is not known; the causes require further investigation.

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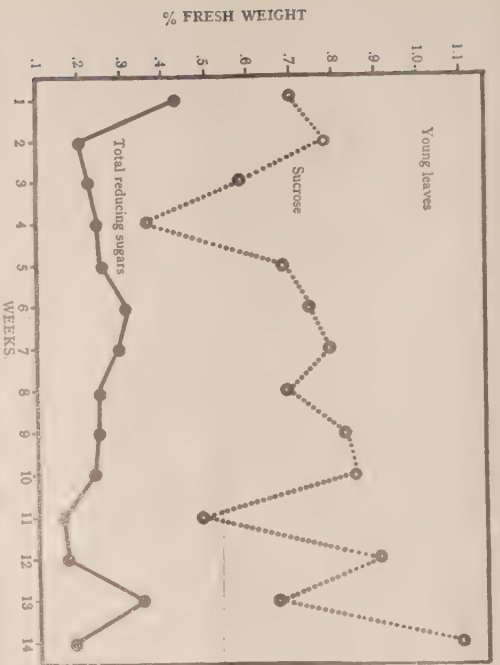


Fig. 2a: Sucrose and total reducing sugars as a percentage of fresh weight in the young leaves during a period of fourteen weeks

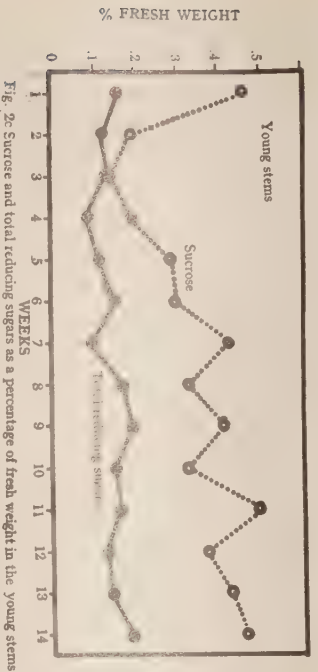


Fig. 2c: Sucrose and total reducing sugars as a percentage of fresh weight in the young stems during a period of fourteen weeks

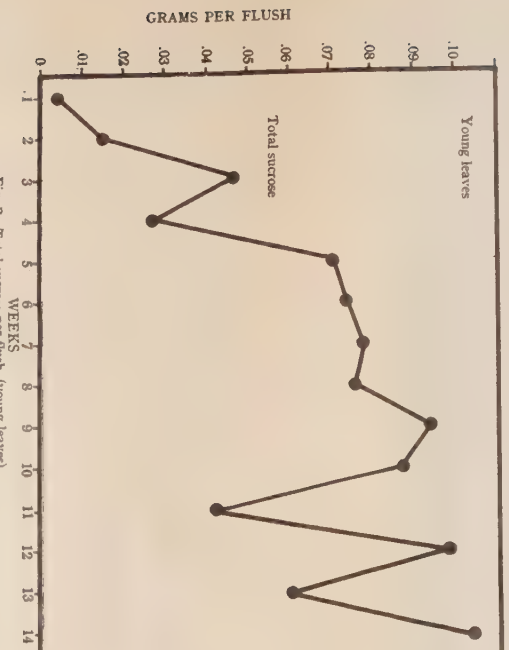


Fig. 2e: Total sucrose per flush (young leaves)

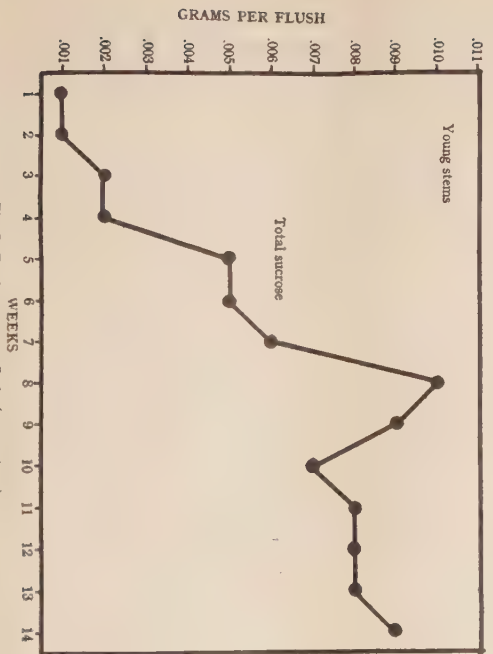


Fig. 2g: Total sucrose per flush (young stems)

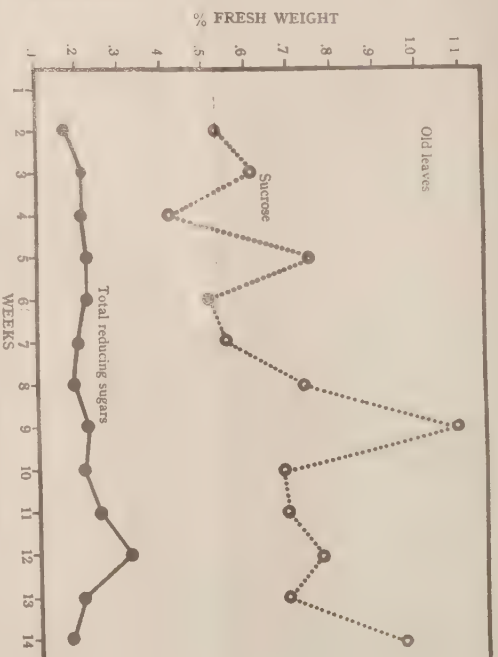


Fig. 2b: Sucrose and total reducing sugars as a percentage of fresh weight in the old leaves during a period of fourteen weeks

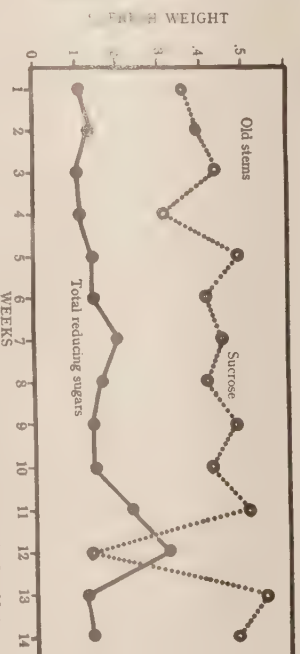


Fig. 2d: Sucrose and total reducing sugars as a percentage of fresh weight in the old stems during a period of fourteen weeks

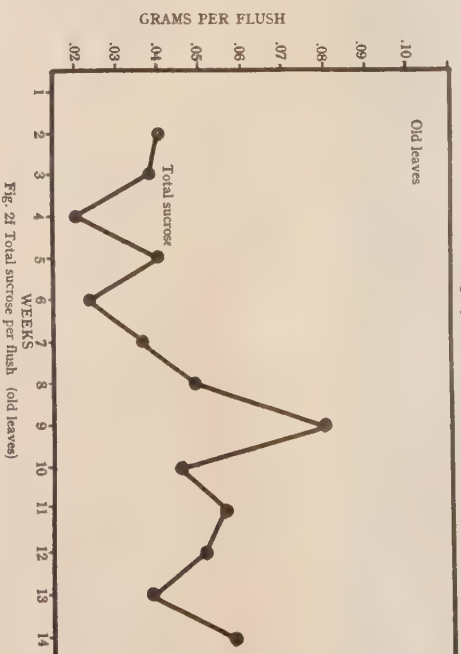


Fig. 2f: Total sucrose per flush (old leaves)

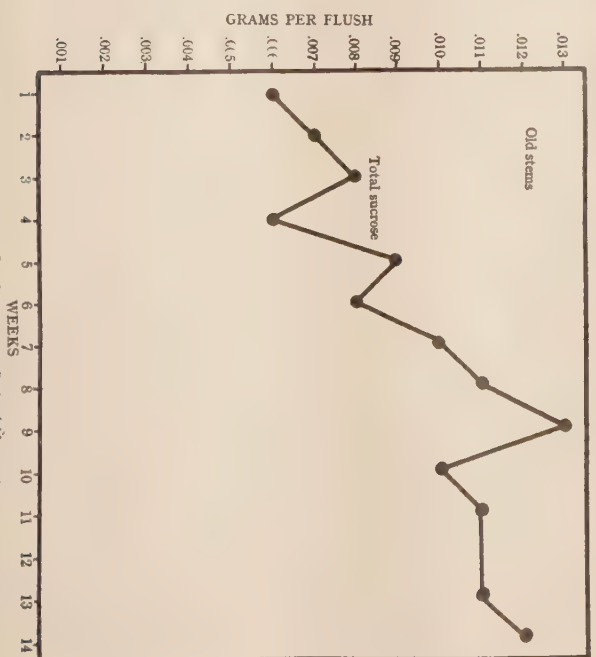


Fig. 2h: Total sucrose per flush (old stems)

(B) DORMANCY OF CACAO BUDS—*Continued*

(III) : THE RELATIONSHIP BETWEEN BUD-BURSTING AND GROWTH OF THE WHOLE TREE

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This investigation forms the third part of the studies of flushing in cacao trees with the primary object of ascertaining the connection between periodic bud-development and the growth of the whole tree. Extensive observations (MacDougal, (1, 2, 3, 4)) on temperate trees have shown the nature of the relationship between bud-development and increase in girth. Few data in regard to growth of tropical trees are available, so that observations on the cacao tree should have both general and special interest. It was also hoped that some information might thereby be forthcoming regarding possible water deficits in the cacao tree during the dry season.

The dendrometer employed in this investigation was kindly supplied by Dr. D. T. MacDougal. It consisted of a number of links of aluminium alloy fastened round the trunk of the tree and carrying a floating frame of "Invar" steel. The changes in diameter of the trunk were read off on a millimetre scale. The magnification provided by the instrument was approximately twenty-five. The instrument is fully described by MacDougal (3).

The dendrometer was attached at a height of about 1 metre from the ground to the trunk of a cacao tree in the grounds of the Botany Department of the College. This tree was well shaded by a large Saman tree. The diameter of the cacao tree at the point of attachment was about 11 cm. Readings were taken twice daily at 8.30 a.m. and 3.30 p.m. With some exceptions where gaps occur in the records, the general trend of the fluctuations in diameter of the trunk is quite clear from the collected data.

Readings were commenced in July, 1941, or about one-and-a-half months after the rains had commenced, and have been continued to the present time (December, 1942). In addition to recording the diametral variations, special note was made of the time when new leaves developed and whether this activity was confined to a few buds only or was general over the whole tree. The fluctuations in variation in branch diameter mean (of the two daily readings) are shown in Figure 1 where the daily rainfalls have also been plotted. The times when bud-bursting was just apparent have been shown by downward-pointing arrows, and the times when the leaves "hardened" (*i.e.* when extension growth of the stem and leaves had ceased) are shown by upward-pointing arrows. The periods when only a few flushes developed on the tree are indicated by small arrows. It was found that the morning readings were usually greater (about half a division) than the afternoon results, except when rain fell during the day. This fact is probably connected with variations in relative humidity of the atmosphere, since, at 8 a.m., the relative humidity is usually high (90-100

per cent.), whereas at 3.30 p.m. it is considerably lower, except on wet days. This is in accordance with the observations of MacDougal (2) and of Pyke (5) who points out that the curve of variation in diameter of *Hevea brasiliensis* closely follows that of atmospheric relative humidity.

During the course of the experiment, it soon became apparent that rain had a marked effect in swelling the trunk of the cacao tree. This is the hydration effect already noted by MacDougal (4). Reference to Figure 1 shows, for instance, that heavy rain in the first half of August, 1941, caused continuous increase in the diameter of the trunk. Such increases, however, were in all cases only temporary, and the trunk contracted again in dry weather or when there were only slight intermittent showers.

The variations exhibited a different pattern when bud activity commenced. The first flush took place in September, 1941, and there was a continuous increase in diameter for a period of about 8 days, after which the readings remained high for a time and then fell again to approximately the same value as before the flush. The fall in value corresponded to the time when leaves of the new flush had hardened. The increase in diameter appeared to take place a few days before any change in the buds occurred, but since individual buds were not kept under observation, it was not possible to verify this point; it would be necessary to keep a representative number of buds on the tree under intensive observation in order to decide definitely. During this particular flush, some rain fell but not sufficient to account for the prolonged high value for the trunk diameter. If it is true that leaf-bud development in the cacao tree slightly precedes diametral increase, it is contrary to the condition usually found in temperate trees where swelling of the trunk does not usually take place until they have reached about half their mature size which may be as much as a month after the buds have burst.

The second flush of any importance occurred about the beginning of February, 1942, when a very marked increase in diameter of the trunk occurred practically simultaneously with bud development. The readings remained high for about 14 days and then, when extension growth was ceasing, the values fell again to a level somewhat above that of the initial value. The effect of this flush on changes in diameter of the trunk is rather remarkable, considering that it occurred in the middle of an unusually severe dry season. The increase in diameter at the time of this flush was greater than during any of the other flushes.

After this flush, the weather continued to be extremely dry until the end of April, so that the existence of any marked water deficits might

be expected to show up by contraction of the trunk. Such was not observed, unless it was masked by an actual increment of growth following the February flush. It was clear, however, that the peripheral tissues had dried out considerably because two small rain showers in March had a marked effect in rapidly increasing the trunk diameter, and the rains at the end of April caused an even greater increase in diameter. This effect, as before mentioned, was only temporary. Rain which fell around the 10th and 17th May caused corresponding effects on the diameter increase, and very heavy rain falling at the end of May and the beginning of June increased the reading up to the highest value attained during the February flush. Evidently rain at the end of the dry season causes a greater hydration effect than at the height of the rainy season when the peripheral tissues are in a condition to retain moisture and when desiccation is not so severe. Another big flush occurred about the beginning of September, accompanied by a simultaneous increase in diameter. This flush was somewhat prolonged because all the buds did not burst within a short period, and consequently the diameter of the trunk did not decrease again until the middle of October.

Discussion

The diametral increases of the trunk of the cacao tree at times of leaf-flush are undoubtedly due to cambial activity, and it is likely that at such times a ring is laid down in the wood. Thus at times of flush, the increase in diameter is probably caused by the swelling of the cambium and the formation of tissue-derivatives, whereas swelling at times of rain results from the hydration of the external tissues of the bark. If the tree is able to utilise water absorbed by the bark, it would indicate that, during the dry season, a slight shower of rain may partly restore the water balance of the tree, although its effect on soil moisture content may be quite negligible.

The net growth in diameter of the trunk was small during the period of investigation (18 months), and it is rather difficult to estimate when most growth took place because of the wide variations caused by changes in hydration. There appears to have been an increase in diameter of about 0.04 mm. between August, 1941, and January, 1942, and after the February flush, a further permanent increase of about 0.06 mm. occurred, which is surprising considering that this was the driest part of the year. In the wet season of 1942, there was a further net increase of about 0.1 mm.

These observations constitute a preliminary study of the relations between leaf expansion and cambial activity of the cacao tree; they indicate that tropical trees may differ markedly from temperate trees. In the latter, cambial activity is initiated in the trunk sometime after leaf development commences; it continues more-or-less throughout the growing season, while in the former, periodic bursts of cambial activity occur, associated with leaf development. It is important to decide how far these periods of cambial activity in the cacao tree are associated with flower formation and development, especially as in cacao the flowers originate directly on cushions on the old bark.

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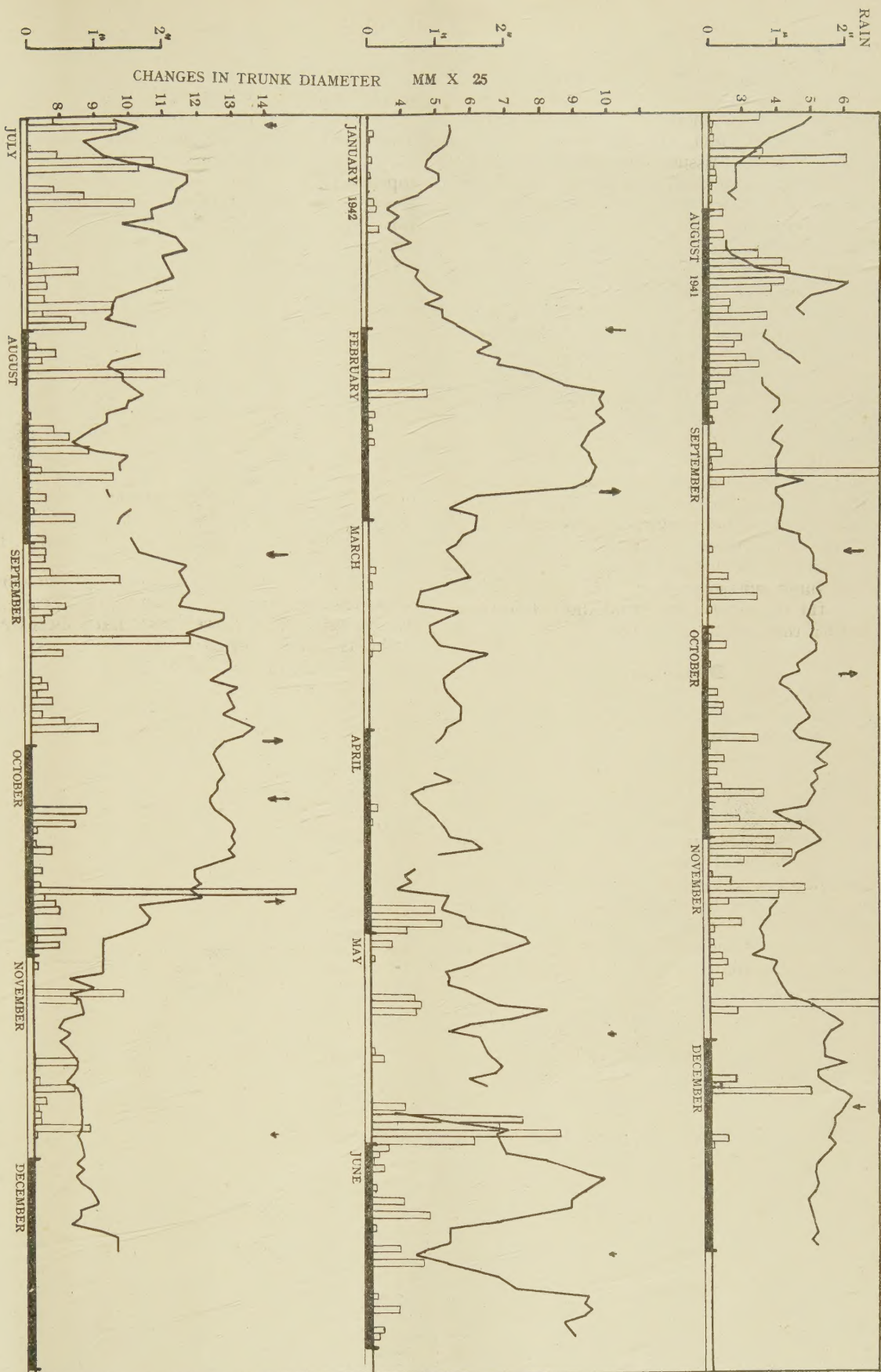


Fig. 1. Diurnal changes in diameter of a mature cacao tree showing the behaviour in relation to periods of flush and the daily rainfall.

